Annual Report
April 80 - May 81
Research Unit 567

THE TRANSPORT AND BEHAVIOR OF OIL SPILLED IN AND UNDER SEA ICE

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I. Summary of Objectives, Conclusions and Implications

Research conducted during FY80 was directed towards improving our understanding of the fate of crude oil spilled as a result of petroleum development in the coastal waters off the north coast of Alaska. A considerable literature exists on the climatology, meteorology, oceanography and ice character of the Prudhoe Bay lease area. Work has been completed by RU562 on the potential for oil pooling under sea ice and by RU568 on under-ice transport of oil by currents. A major objective of our work this year was to synthesize this information into a meaningful set of oil spill scenarios for the Joint Lease Sale area at Prudhoe Bay and also for the Sale 71 area of Harrison Bay. Results indicate that an oil spill under the ice from November through April would become incorporated rapidly into the ice. Subsequent transport of the ice then determines the point at which oil is released, essentially unweathered, during spring breakup. Ice inside the barrier islands remains in place through the winter so the oil will be released to the water in essentially the same spot in spring. This stable concentration of oil may aid in cleanup operations.

Ice outside the barrier islands can be transported long distances during a single winter. To investigate the possibility that oiled ice from the Prudhoe Bay lease area might enter the Chukchi Sea and travel south through the Bering Straits, the ice dynamics model developed during AIDJEX was applied to the Chukchi. Under conditions of low ice strength it was found that the ice could travel over 400 km in 3 months implying considerable motion in the Chukchi though not to the extent of transporting ice from Barrow through the Bering Strait.

Very little is known about the behavior of oil after its release from the ice. A preliminary study has been carried out to determine the interaction of oil with low to medium concentrations of ice. Transport of oil appears to be controlled by herding of oil by ice floes with the result that the ice drift controls oil slick drift. Dispersion of the oil is controlled by turbulence in ice motions.

II. Introduction

A. General Nature and Scope of Study

This study synthesizes work on sea ice dynamics with available information on the behavior of oil spills to provide a basis for predicting the behavior of oil spills in the Arctic. Details of the interaction of oil from a blowout with an ice canopy are evaluated for a variety of ice conditions varying with geography and season. Effects of ice on dispersion, weathering and transport are considered. Ice transport is modeled numerically using a sea ice dynamics model. A field program was initiated to observe ice motions for model verification.

B. Specific Objectives

A study of ice motion in the Chukchi Sea using the ice dynamics model was made to determine the conditions under which ice breakout from the Chukchi to the Bering Sea may occur. The results of this work are given in FRC Report No. 168 which is given as an appendix to this report.

Another objective was to develop a set of twelve representative oil spill scenarios for the Prudhoe Bay lease area. The time, magnitude and location of the spills were selected by OCSEAP. The scenarios were to describe the fate and behavior on an oil spill under ice from initial release through to the release of oil into open sea water. As a prerequisite to these scenarios a compilation of the relevant meteorological, oceanographical, ice dynamic and oil property data was required. This information is given in Flow Research Report No. 175. It serves as a reference for the twelve Prudhoe Bay oil spill scenarios given in Flow Research Report No. 176. Both reports are included here as appendices.

Flow Research Report No. 189 describes the fate of oil released under the ice in the Harrison Bay offshore area. The fate of oil released onto the water surface and its interaction with low to medium concentrations of sea ice is not well known. A third objective was thus to develop a preliminary guide to the mechanisms which affect the interactions of surface oil slicks with drifting ice.

The last objective for RU 567 was to initiate field studies of ice motions in Norton Sound. Seven tracking buoys were deployed in Norton Sound over the course of the 1980 winter. The trajectories of the buoys will be analysed with the object being to verify an ice dynamics model in this area.

C. Relevance to Problems of Petroleum Development

Large portions of the Alaskan continental shelf are being considered for petroleum and gas development. An oil spill in these waters could have drastic consequences for a number of wildlife species. A knowledge of the disperson and transport of oil spilled in Alaskan coastal waters can be used to develop clean-up plans and to protect sensitive wildlife areas. Slick behavior studies can also be used to evalute the likelihood of climatic effects. Ice motions present a hazard to structures associated with offshore development. A combination of field and numerical ice dynamics studies may be used to identify hazardous areas and to forecast ice conditions for drilling operations.

III. Current State of Knowledge

The ice dynamics of the Beaufort Sea has been well characterized by the results of AIDJEX and subsequent modeling efforts. Ice outside the stamukhi zone can travel from Prudhoe Bay to Barrow in a few months. Ice within the Barrier Island lagoons is stable. Studies by RU 562 have determined the potential for oil pooling under an ice canopy. RU 568 has studied the conditions necessary for currents to transport oil under ice. Essentially these studies imply that oil will pool under the ice in layers 1 cm to 10 cm thick depending on the small scale surface roughness. Currents of 20 cm/s or more are required to cause appreciable oil pool motions. A considerable literature exists on the oceanography and meteorology of the coastal Beaufort Sea and the Bering Sea while the Chukchi Sea is still relatively unknown. Detailed ice motion studies have been restricted to the Beaufort Sea. Ocean currents cause a large part of the mean monthly ice transport while winds cause considerable seasonal variation as well as daily variability in the motion.

IV. Study Area

The oil-ice study area includes the Joint Lease Sale area at Prudhoe Bay and the proposed Sale 71 lease area to the west near Harrison Bay. The Chukchi Sea is modeled in ice breakout studies and ice motions were observed in a field study in Norton Sound.

V. Sources Methods and Rationale of Data Collection

The field study in Norton Sound was made using ADAP buoys deployed on the ice by helicopter on three occasions. The initial deployment consisted of three buoys placed along the length of Norton Sound in late January. As the ice drifted out of Norton Sound, to be replaced by new ice growth, additional buoys were deployed in locations providing the best coverage of ice motions. Data buoy locations are available every 3-6 hours.

VI. Results

The numerical study of Chukchi Sea ice dynamics (FRC 168) has successfully modeled the ice motions during breakout. Motion is concentrated in a band about 150 km wide off the northwest coast of Alaska from Cape Lisbourne to Pt. Barrow. Breakup is initiated by strong current reversals to the south which carry the ice through the Bering Straits. Ice strength is important in the Chukchi as a structural arch is developed during southward motion. During the 1976-1977 winter season modeled motions were not large enough to carry ice from Barrow through the Bering Strait.

The ice-oil study (FRC 175) shows that any oil spilled during the winter season will be released to the water during spring breakup. The oil spilled will be trapped by small scale under ice relief in relatively small areas and become encapsulated in the ice in a very short time. Outside the barrier islands large amounts of ice are incorporated into ridges implying that oil spilled near the stamukhi zone will end up in a ridge.

The scenarios presented in FRC 176 for the the joint lease sale area near Prudhoe Bay are very similar to the predicted behavior in the sale 71 lease area near Harrison Bay (FRC 189). In this area shoals offshore act to ground ridge systems which then protect the nearshore ice just as the Barrier Island protect Steffanson sound. Currents in both areas are quite small and should not transport oil under the ice. Early season deformation can be significant in the sheltered areas but the ice becomes strong enough by December to become essentially fast.

Preliminary results indicate that low to medium concentrations of ice influence the transport and diffusion of oil slicks by herding the oil. At high enough ice concentrations the oil essentially moves with the ice. Under these conditions dispersion of the oil will be controlled by diffusion of points on the ice.

Preliminary results from the Norton Sound buoy study indicate continuous motion of ice out of Norton Sound to the west. Ice motion in the northern Bearing Sea is generally southward but the region north of Norton Sound tends to have a generally northward motion. Reversals of ice motion are significant and are apparently correlated to storms.

VII. Discussion and Conclusions

Oil spilled beneath the fast ice in either lease area will be limited in extent and will not move far during the winter. Drilling regulations stipulating containment berms to be constructed around each drilling platform should prove an effective means of further enhancing the containment of even a large spill. Regulations limiting the drilling season to the end of March allow 2 months to recover spilled oil and drill relief wells further minimizing the danger of an open water spill at breakup. Once oil is released into the water cleanup efforts will become very difficult.

Oil spilled outside the fast ice zone will in all likelihood be incorporated into ridges and possibly transported large distances. The release of oil from ridges is an important process which is likely to be very different from the release by flat ice.

Oiled ice could reach Barrow but it is unlikely to travel through the Bering straits. Oiled ice from future lease areas in the Chukchi, however, might well travel into the Bering Sea because the release area is much closer to the Bering Strait.

VIII. Needs for Further Study

Several questions have been raised by the results of these studies. Oil spilled outside the barrier islands becomes incorporated into ridges. The location of the oil in the ridges and the means by which the oil is released are important unknowns since these factors will control the location, time and amount of oil released.

The dispersion of oil in low to medium concentration ice will be controlled by horizontal diffusion of the ice. Turbulent diffusion coefficients, for sea ice would provide useful estimates of the dispersion of an oil spill during spring breakup.

The performance of the ice dynamics model in the Chukchi Sea has not been validated as it has in the Beaufort Sea. Chukchi Sea ice is different from Beaufort Sea ice in that it is mostly first year growth. A simultaneous data set including wind currents and ice conditions is needed to drive a model calculation for comparison with a set of data buoy trajectories.

The sea ice dynamics model for the Chukchi should be improved to account for the weakening effect of lead formation off the Alaskan coast. The present model does not allow weakening and probably underestimates the possible ice motions.

The buoy motions obtained for Norton Sound and the Northern Bering Sea should be used to validate the Rand Ocean Model developed by RU 435. This would require some measure of the driving forces for the model. An evaluation of the buoy motions should be made to determine effects of long term currents, storm events and tidal motions.

IX. Summary of Fourth Quarter Operations

A. Field Operations

(1) 3 trips to Norton Sound

(a) 8Jan - 20 Jan, buoys 3600, 3601 and 3602

(b) 11 Feb -19 Feb, buoys 3603 and 3605

(c) 13 March -15 March, buoys 3604 and 3606

(2) Personnel Involved

Don Thomas - research scientist, Flow Research Company

Jack Kollé - research scientist, Flow Research Company

(3) Methods

Buoys were assembled and tested at the airport in Nome. Deployment was by helicopter.

(4) Data Collected and Analyzed

Buoy trajectories are being collected and edited at Flow for presentation to the OCSEAP data bank. Only visual analysis is expected during this project.

JK/184R

COVER SHEET FORMAT

Proposal/Revision Date: 9/9/81

TO: National Oceanic and Atmospheric Administration
OMPA/OCSEAP
P.O. Box 1808
Juneau, AK 99802

Contract #: 03-78-B01-61
NOAA Project #:
Institution ID#: FRC Prop. #82

RECEIVED SEP 11 1981
Office of Marine Pollution Assessment
Alaska Office

PROPOSAL

Research Unit Number 567

TITLE: The Transport and Behavior of Oil Spilled In and Under Sea Ice

Cost of Proposal: $100,000 Lease Areas Diapir (Beaufort Sea) 100 %
(If joint proposal, show cost for each institution; if more than one year, show cost for each year (SEPARATE BUDGET SHEETS ALSO REQUIRED).
Period of Proposal: Sept. 81 - Dec. 82

PRINCIPAL INVESTIGATOR(S):

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INSTITUTION (include Department, if appropriate)

Flow Research Company, a division of Flow Industries, Inc.

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2. Qualifications of Principal Investigators

Dr. R. S. Pritchard, a senior research scientist and manager of the Geomechanics Department at Flow Research Company, (FRC) is an experienced investigator in the study of polar air-ice-sea interaction problems, especially the dynamic behavior of sea ice. His Arctic experience began with the AIDJEX project in 1973, for which he served as a co-principal investigator. Dr. Pritchard has also been a principal investigator on OCSEAP projects since 1976, including several modeling efforts and buoy deployment programs in the Chukchi Sea and Norton Sound. He is one of the scientists primarily responsible for the development of the AIDJEX sea ice dynamics model, and his vast modeling experience will provide the guidance needed to understand the behavior of the Beaufort Sea ice cover. Dr. Prtichard is an internationally known researcher who has authored or co-authored nearly 60 publications.

Mr. D. R. Thomas, research scientist in the Geomechanics Department at FRC, brings both a modeling background and field experience to the team. Mr. Thomas is another former AIDJEX staff member, having worked on that project since 1973. He is a computing specialist who provides especially effective results in using the AIDJEX sea ice model. He also has a strong background in statistics and data processing, which is necessary for validating the performance of the model in this important project. Mr. Thomas has been an important investigator in previous OCSEAP studies. Recently, his synthesis and development of scenarios relating to the fate and behavior of oil spilled in Prudhoe Bay has received widespread acceptance by Arctic investigators. Mr. Thomas provides a balance of theoretical and field experience with his understanding of the important portions of this problem.

Flow Research Company is committed to the growth of its Arctic Research program. This commitment began in 1978 with the hiring of the two principal investigators assigned to this project. Since that time, Dr. J. J. Kollé, a fracture mechanics specialist who has taken part in the OCSEAP buoy deployment in Norton Sound, has joined the Geomechanics staff. Other FRC staff members have also been involved with this ongoing research project for OCSEAP, including Dr. J. C. Schedvin, an oceanographer who has become familiar with the ocean current patterns in the Chukchi and Beaufort Seas. These scientists are now an integral part of the research staff at Flow Research Company.

3. Technical Proposal

I. Title: The Transport and Behavior of Oil Spilled in and Under Sea Ice
Research Unit Number: 567
Contract Number: 03-78-B01-61
Proposed Dates of Contract Extension: The additional tasks proposed in this extension run through December 31, 1982.

II. Principal Investigators

R. S. Pritchard, Sr. Research Scientist and Manager
Geomechanics Department
Flow Research Company
Mr. D. R. Thomas, Research Scientist
Geomechanics Department
Flow Research Company

III. Proposed RU Budget

A. Total Cost $100,000
B. Percentage Distribution of Total by Lease Area, Diapir Field (Beaufort Sea) 100%.

IV. Background

This research unit has conducted studies of the transport and behavior of oil spilled under sea ice. The work has included the determination of the range of likely motions of the Beaufort Sea ice cover (Thomas and Pritchard, 1979). In this work, the motion of the ice cover was carefully evaluated to determine how well a free-drift model could perform in simulating the large-scale motion of the ice cover in the Beaufort Sea. This work showed that the free-drift model is useful for estimating monthly ice motions and for showing intra- and interannual variability of the ice motions.

Another study involving sea ice motion in the Chukchi Sea (Reimer et al., 1980a and b, 1981) considered the possibility of the transport of oil southward from Point Barrow through the Chukchi Sea and Bering Strait. Long-term mean northward currents show strong reversals (Coachman and Aagaard, 1981) that can cause breakout of the structural arch across the Bering Strait, allowing large southward motions of the Chukchi Sea ice cover. Reimer et al. (1981) showed that, even under the most extreme conditions, it is unlikely that oiled ice could be transported from Point Barrow through the Bering Strait. They also identified ocean currents as the important driving force of the motion of the ice cover in the Chukchi Sea. This detailed study of the behavior of the Chukchi Sea ice cover utilized the theoretical sea ice model developed during AIDJEX (Coon, 1980) with refinements and modifications as described by Pritchard (1981).

A recent study by Pritchard and Kollé (1981) provided an estimate of the level of performance that can be expected of the refined AIDJEX model in the Beaufort Sea. In this study, it was found that the daily motion of the ice cover at any point can be simulated within a mean vector error of 0.01 meters per second and a standard deviation of about 0.035 meters per second. While these errors include inaccuracies in the physical model, the largest error sources are in the winds and ocean currents used to drive the model and in the description of initial ice conditions and boundary conditions.

More recent work in the development of this model has provided an alternative formulation of the ice conditions. This is a modified ice characterization that can replace the thickness distribution of Thorndike et al. (1975). The modified formulation, developed by Pritchard and Coon (1981), describes the ice conditions in terms of the fractions of open water, thin ice, flat ice and rubble. This simpler characterization allows for easier comparisons with remote satellite imagery.

During the last year, this research unit has been involved with synthesizing the results of our work and that of others to describe the expected behavior of oil spilled in and under sea ice. In a pair of reports, Thomas (1980a, 1980b) evaluated the individual mechanisms that control the interaction of oil and sea ice and developed a set of scenarios describing the likely oil behavior under a variety of spill conditions. Twelve scenarios were developed for assumed blowouts in the vicinity of Prudhoe Bay, Alaska. It was assumed that a blowout could occur in either the fall or the spring, that the blowout could occur under fast ice, the stamukhi zone or the moving pack ice and that the duration of the blowout would be either 5 days or 90 days with a spill magnitude on the order of 50,000 barrels of oil per day. These conditions cover the most likely and the most extreme conditions. To develop the scenarios, Thomas (1980a) synthesized the results of all previous studies to determine the most likely behavior of the oil. This information provided a major contribution to the 1981 Synthesis Report developed for Harrison Bay.

As part of this work, it was noted that the bottomside relief of the level ice cover provides the primary features that entrap oil. (It was previously been believed that the dominant roughness feature capable of trapping oil was large ridges.) Thomas concluded that even extremely large amounts of oil will be trapped within a region a few kilometers diameter surrounding the blowout site. After the initial rise and gravity spreading to fill the relief in the bottomside of the ice, low temperatures will freeze and trap the oil in lenses under the ice. Transport and spreading of the oil during the freezing season then will occur only as the ice cover moves and deforms. As a result, we observe that the critical time of the year begins with the spring thaw in the following year. At this time, the oil that has not been cleaned up and remains entrapped in the pockets under the ice cover will rise through brine channels in the ice. The melting of the ice cover will be enhanced by several weeks due to the presence of this oil on the surface. After this time, the oil will be released to the ocean surface and will essentially act as though it were spilled at this time of year.

Thomas (1981) has compared the fate and behavior of oil spilled under ice in both Harrison Bay and Prudhoe Bay. He has compared the different wind and current conditions, as well as the different geographic features. The presence of shoals offshore in Harrison Bay allows grounded ridges to form early in the year, and these serve as protecting features similar to the offshore barrier islands at Prudhoe Bay. As a result, we have concluded that the expected behavior of oil spills in the Sale #71 area of Harrison Bay is not grossly different from that at Prudhoe Bay.

In the proposed work, we will use model simulations to define the conditions whereby oiled ice from the nearshore lease areas may be incorporated into the pack ice. This will enable us to bridge the gap between previous studies on oil-ice interactions and pack ice trajectories. This is a natural extension of the work that we have done since the inception of RU #567. We expect to focus primarily on the smaller-scale nearshore ice behavior and to identify differences along the North Slope of Alaska due to geographic and weather conditions.

V. Objectives

The objectives for this research unit in the extended FY81 scope are:

(1) To review the results of previous winter transport calculations, which use the modified AIDJEX model and improve the boundary conditions and shear zone dynamics of the model, as appropriate, based upon the more recent field data on meteorology (RU #519), ice velocity vector fields (RU #267) and the existing network of drifting buoys in the Beaufort Sea.

(2) To produce specific oil spill trajectory predictions using the refined AIDJEX model.

(3) To synthesize scenarios for oil spills, their transport and the ultimate fate of the oil for the entire Diapir Field (#87) lease area.

The results of the proposed study are critical to the general objectives of assessing environmental conditions on the Alaskan Continental Shelf and determining the effect of petroleum development. Our previous work has indicated the need for near shore ice motion information, because this is the individual factor that controls the motion of an oil spill. Objective 1 will allow us to focus our study on the smaller-scale behavior of the ice cover, in order to identify differences in ice behavior in different locations along the North Slope of Alaska. The second objective will allow us to make specific predictions of oil spill trajectories in terms of the ice motion at these locations. The final objective will allow us to synthesize results of this study and other OCSEAP studies for the Diapir Field (# 87) lease area. Since the focus of this research unit is to synthesize results of this and other studies, its importance on providing information for decision making, both prior to and during offshore oil and gas development, is obvious. This project serves as a first-cut synthesis of the reports of other investigators and leads to an enhancement of the general synthesis meeting that is required for each lease area.

VI. Strategy and Approach

A primary problem to be addressed in this year for Research Unit 567 is to determine possible oil spill trajectories during the winter. We will use available field data from other research units and the previous modeling results of Research Unit 567, but additional calculations will be necessary. As indicated in the background section of this proposal, our previous work has provided acceptable ranges of behavior of the pack ice cover far from shore. For this context, far from shore is on the order of 400 kilometers. Our task therefore, is to determine oiled ice trajectories within the nearshore region. It is within this region that the effects of ice stress become important, and the closer to shore the more important these become.

Our strategy will be to select a typical range of atmospheric, oceanic and ice conditions and to determine the ice trajectories for these cases. The ice trajectories will be from nearshore locations within the Diapir Field lease area. A theoretical model will be used to determine limits of motion of the ice cover for various driving forces and ice conditions. For example, early in the winter season the ice cover is thin and strength is low. Later in the year, thermal growth thickens the ice so that a transition between free drift and a very strong ice cover occurs. Early in the year large motions can be expected in the vicinity of the barrier islands. As the ice cover thickens and becomes stronger, the fast ice forms near shore causing a smoothing effect between shoreline projections. The formation of large ridge systems on the Continental Shelf in these areas also serves to increase the strength and to force the deformations seaward. Later in the winter, the location of the areas in which shearing is dominant moves seaward. At this time, we expect little motion shoreward of the large grounded ridge systems.

To satisfy objective 1, we will evaluate several previous calculations for the Beaufort Sea region. These include the results of Pritchard, (1980, 1981), who made large-scale simulations for an 18-day period when two storms passed; these represent a typical set of conditions for the Beaufort Sea. In evaluating Pritchard's approach, we will carefully study the thickness distribution formulation used in this model with an eye toward modifying it to the latest ice characterization developed by Reimer et al. (1980b) and Pritchard and Coon (1981). This four-component characterization of the ice cover appears to be useful in defining the essential physics needed to estimate ice strength and is simple enough to reduce the numer of free parameters to a mangeable set. We will also obtain and examine the ice motion and atmospheric pressure data from the FGGE buoys. The observed ice motions provide far-field boundary conditions for smaller-scale model simulations of the region within a few hundred kilometers of the North Slope of Alaska. Typical wind patterns can be computed from the observed atmospheric pressure fields. We can then design a set of model simulations driven by observed winds and boundary conditions which will provide us with typical nearshore ice trajectories.

To satisfy the goals of objective 2, we will make calculations using the refined AIDJEX model. It is expected that typical conditions in the region can be defined for approximately a l-month period. Our approach will be to limit the duration of simulations to this length, assuming that we can accumulate ice motions beyond the l-month period if necessary. To define the range of oil spill trajectories, we expect to perform additional simulations that will serve as a parameter study. We will vary parameters such as strength to represent conditions at different times of year. It is possible that these simulations will be performed with uniform and constant strength so that the thickness distribution formulation will not be necessary for these ideally plastic simulations (for example, Pritchard, 1980).

To satisfy objective 3, we will review the synthesis of data performed under Research Unit 567 for the joint lease sale in Prudhoe Bay and for the Harrison Bay (#71) lease sale. We will identify differences in the behavior of oil spills due to the finer resolution of the proposed study. The focus of this year's work will be to synthesize the oil spill transport information for the entire Diapir Field (#87) lease area.

VII. Deliverable Products

A. Digital Data

There are no data to be acquired under these tasks.

B. Narrative Reports

An annual report will be prepared and submitted by April 1, 1982. This report will include a description of the progress to date. We will also incorporate final copies of the individual reports prepared in the prior year.

A report describing procedures and results of the ice trajectory modeling for the Diapir Field area (#87) will be prepared by September 1982.

A report describing the oil spill scenarios in the Diapir area will be prepared by November 1982. This report will represent a synthesis of information of this research unit and will allow us to evaluate previously developed scenarios and to estimate changes due to added information in these new areas.

The principal investigators will participate in the synthesis meeting for the Diapir Field lease area in November 1982.

C. Visual Data

It is expected that the oil spill trajectory predictions will be presented on maps. These map products will be submitted to OCSEAP in Universal Transverse Mercator projections with a scale to be determined jointly by the contract supervisor and the principal investigators. These maps will be submitted in reproducible form and included in the reports to be submitted under this research unit..

VIII. Milestone Chart

The milestone chart is included in Section 6 of this proposal package.

IX. Logistics Requirements

No logistics are required for this work.

X. Anticipated Problems

Because the principal investigators have many years of experience in studying sea ice dynamics simulations, we do not expect any insurmountable problems to occur during the course of this study. We have an existing computer code capable of performing the simulations that we have described. We have experience at studying the output from this code, interpreting it in terms of ice motion and building these observations into oil spill trajectories. The primary difficulty anticipated during the course of this study is that enough model simulations must be done at a fine-enough spatial resolution to provide realistic ice trajectories for a range of ice conditions, atmospheric conditions and geographic configurations. The mathematical model is expected to adequately describe the sea ice behavior on these small scales (5 to 10 kilometers), and the numerical scheme appears adequate. However, the costs of such calculations can be high, and care must be exercised in choosing which calculations to do. In case the computer code in its present configuration becomes too expensive, we would expect to follow several standard numerical techniques to modify it. The first of these is to perform nested calculations in which preliminary large-grid-scale simulations are first performed to provide boundary information within some smaller portion of the domain. This is a well-known technique in other fields of study. At the same time, we will look at other computer codes based on finite element logic that give more freedom in defining grid connectivity than the refined AIDJEX code does. Such coding changes would not entail changes to the physics of the model but would be purely computer programming changes. With these two backup opportunities, we expect to be able to solve any problems that arise.

XI. Information Required from Other Investigators

To review the results of previous winter transport calculations based on more recent field data on meteorology and ice velocity vector fields, it will be necessary to contact the principal investigators of Research Units 519 and 267. In addition, it will be necessary to obtain information on the ocean current fields in the nearshore Beaufort Sea over the Continental Shelf. This will require discussions with Knut Aagaard and others working on that research unit. We have not identified the specific requirements in either the amount or content of the information required from these investigators. However, since we have worked in the past with all concerned parties, we feel there will be no difficulties in obtaining the information in a timely and accurate manner.

XII. Outlook

The proposed work will provide valuable and necessary information in developing scenarios for the fate and behavior of oil spills in the Diapir Field (#87) lease area. The proposed approach will allow us to determine oil spill trajectories during the times of year when oil is incorporated into the ice cover and the oil's motion is defined by the ice motion. It must be emphasized however, that inadequate work has not yet been performed to adequately define the motion of the oil with respect to ice during spring breakup when the oil is released from the bottom relief of the ice cover and can move on the surface of the open water between the uncompacted flows. In addition, and perhaps even more importantly, work has yet to be done in defining how oil is incorporated into ridges built from oiled ice. In our previous work, Thomas (1980a) found that large fractions of ice are built into the ridges and the likelihood of oiled ice being built into a ridge is substantial. The importance of oil in ridges comes about because our results have shown that no matter when a spill occurs it is released to the open water in spring in an essentially unchanged condition. Thus, every spill is a spring spill. However, oil built into ridges could be released more slowly, thereby reducing the rate of release and causing the location of the release to move as the ice or ridge is transported over long periods of time. Until we know where the oil is, and how it will be released at the time of spring melt, it is not going to be possible to determine the final fate of the oil during this melt season.

Due to funding limitations, several tasks originally proposed for Research Unit 567 aimed at addressing the above questions have been postponed. It is still believed that these tasks should be performed in order to better define the expected behavior of oil spills in, over and under sea ice. It is expected that the laboratory experiments required to learn where oil is located in ridges and the computer simulations and validation data needed to determine the history of the development of the stamukhi zone will require approximately $150,000. Since this work will enhance and extend the scenarios and synthesis of information for the Diapir Field, it can be performed after the synthesis reports are prepared. Although this will not allow input prior to writing of the environmental impact statement for leasing this area, it will provide valuable information for operations afterwards.

XIII. References

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Reimer, R. W., J. C. Schedvin, and R. S. Pritchard (1981) "Chukchi Sea Ice Motion," in POAC 81, Université Laval, Quebec, pp. 1038-1046.

Thomas, D. R. (1980a) "Behavior of Oil Spills Under Sea Ice - Prudhoe Bay," Flow Research Report No. 175, Flow Research Company, Kent, Washington.

Thomas, D. R. (1980b) "Prudhoe Bay Oil Spill Scenarios," Flow Research Report No. 176, Flow Research Company, Kent, Washington.

Thomas, D. R. (1981) "Harrison Bay Sea Ice Conditions Relating to Oil Spills," Flow Research Report No. 189, Flow Research Company, Kent, Washington.

Thomas, D. R., and R. S. Pritchard (1979) "Beaufort and Chukchi Sea Ice Motion, Part 1. Pack Ice Trajectories," Flow Research Report No. 133, Flow Research Company, Kent, Washington.

XIV. Standard Statements

A. Reports will be submitted in accordance with Section VII-B of the proposal. Each required report will consist of an original, reproducible manuscript and nine copies on 8-1/2 x 11 paper.

B. For all biological research, representative voucher specimens will be preserved and labelled in accordance with OCSEAP Voucher Specimen Policy. Voucher specimens will be shipped to an OCSEAP-designated repository before the expiration date of the contract. Costs for the preparation and delivery of voucher specimens should be included in the project budget.

C. Deliverable products will be submitted to the Alaska Office in the form and format specified in Section VII. Digital data submissions will be accompanied by a Data Documentation Form (NOAA Form 24-13).

D. Within 10 days of the completion of a cruise or other data gathering effort, the PI will submit a ROSCOP data collection inventory form (NOAA Form 24-23) to the OMPA/OCSEAP Alaska Office Data and Information Manager.

E. Within 30 days of the completion of OCSEAP provided logistics support, the PI will provide a field operations report to the OMPA/OCSEAP Operations/Logistics Manager.

F. Title for all non-expendable property purchased with OCSEAP funds remains with BLM/OCSEAP pending disposition at contract expiration. An inventory of new non-expendable equipment purchased will accompany the narrative reports. The PI will maintain inventories and record on Form CO-281, "Report of Government Property in Possession of Contractor."

G. The PI and other project staff are prepared to travel to the OMPA/ OCSEAP to discuss the project. Such conferences will be scheduled on dates mutually satisfactory to both parties. In addition, the PI and other project staff will participate in program review or synthesis meetings as requested by OMPA/OCSEAP. It is understood that costs of the travel and per diem for these trips, if not included in the RU budget, will be borne by OCSEAP.

H. All maps will be submitted in Universal Transverse Mercator (UTM) projection at a scale of 1:250,000 or 1:500,000. Other scales or projections may be used after consultation and in agreement with OCSEAP contract supervisor. All maps will also be reduced to 8-1/2 x 11 inches for inclusion in the accompanying reports.

I. The Principal Investigator shall actively lead and supervise the proposed work, and shall take full responsibility for timely completion of all objectives, independent of the percentage of the Principal Investigator's salary requested in the budget.

J. Three (3) copies of all manuscripts prepared for publication or presentation which pertain to technical or scientific material developed under OCSEAP sponsorship, will be submitted to the OMPA/OCSEAP Alaska Office at least sixty (60) days prior to release, for information and for forwarding to BLM. The release of such material within a period of less than sixty days will be made only with prior written consent of the OMPA/OCSEAP Alaska

Office. News releases will first be cleared with the Alaska Office. Five copies of the reprints will be submitted to the Alaska Office.

M. All publications and presentations of material developed with OCSEAP funds will acknowledge BLM/OCSEAP sponsorship. The following acknowledgement will be used:

> "This study was funded (wholly or in part) by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, as part of the Outer Continental Shelf Environmental Assessment Program."

4. Proposed RU Budget

The proposed RU budget is detailed on the budget forms included in Section 6 of this proposal package.

5. Other Information

A. The Arctic Research area of the Geomechanics Program at Flow Research Company expects to have a U.S. government contract with the Office of Naval Research, entitled "Background Noise Generated by Sea Ice Deformations," in the amount of $100,000. This work will require use of the refined AIDJEX model to simulate the mechanical energy budget of the sea ice cover. It is expected that this simultaneous effort will minimize computer programming costs and expenses on the OCSEAP project.

B. The FRC personnel to be assigned for direct work on this project include:

Dr. R. S. Pritchard, PI, Sr. Research Scientist, Manager Geomechanics Department.
Mr. D. R. Thomas, PI, Research Scientist, Geomechanics Department
Dr. J. J. Kollé, Research Scientist, Geomechanics Department
Dr. J. C. Schedvin, Research Scientist, Oceanography Department
Mr. Pat McCafferty, Computer Programmer

In addition, we have retained Dr. Miles G. McPhee, an Arctic oceanographic consultant, to help define and interpret ocean current over the Beaufort Sea Continental Shelf. Dr. McPhee is an experienced scientist whose involvement with FRC scientists began during AIDJEX. He brings a special knowledge of ocean current modeling, especially the effects of ocean currents or sea ice dynamics modeling, to the research team.

Resumes of R. S. Pritchard, D. R. Thomas, and M. G. McPhee are included on the following pages.

C. Persons authorized to conduct negotiations for Flow Research Company are:

Ms. Mary Chandra, Contract Administrator (206) 872-8500

Mr. Roger Haines, Vice President for Finance & Administration (206) 872-8500

Dr. K. J. Touryan, Sr. Vice President and General Manager of Flow Research Company (206) 872-8500

DR. ROBERT S. PRITCHARD
Senior Research Scientist
Manager, Geomechanics Department

Home Address:

11042 Sand Point Way N.E., Seattle, Washington 98125.
Telephone (206) 365-5377

Education:

B.S., Engineering Mechanics, Lehigh University, 1962.
M.S., Mechanical Engineering, University of New Mexico, 1966.
Ph.D., Engineering, University of New Mexico, 1970.

Experience:

Associate Design Engineer, ACF Industries, Inc., Albuquerque, New Mexico, 1962 - 1963.

Research Engineer, Eric H. Wang Civil Engineering Research Facility, University of New Mexico, Albuquerque, New Mexico, 1968 - 1973.

Principal Scientist, Arctic Ice Dynamics Joint Experiment, University of Washington, Seattle, Washington, 1973 - 1978.

Consultant, R. S. Pritchard Consulting, 1975 - 1978.

Senior Research Scientist, Manager, Geomechanics Department, Flow Research Company, Kent, Washington, 1978.

Specialization:

Solid mechanics, applied mathematics, plasticity, numerical analysis, Technology transfer from mechanics to important applied problems in geomechanics.

Professional Societies:

American Academy of Mechanics
American Geophysical Union American Society of Mechanical Engineers
International Society for Rock Mechanics Phi Kappa Phi Pi Tau Sigma
Society of Sigma Xi

Publications:

Dr. Pritchard has authored or co-authored over fifty-three publications and reports, primarily in the area of ice, soil and rock mechanics.

DR. ROBERT S. PRITCHARD (Cont.)

Senior Research Scientist
Manager, Geomechanics Department

Publications: (Cont.)

1. R. S. Pritchard and J. V. Timmons, "57 Case Structural Test," Report No. 144, ACF Industries, Albuquerque, New Mexico, December 1962.

2. M. W. Wildin, W. E. Putnam and R. S. Pritchard, "Temperature and Thermal Stress Distributions in Circular Cylinders," Technical Report ME-11, the University of New Mexico, Engineering Experiment Station, Albuquerque, New Mexico, August 1964.

3. R. S. Pritchard and M. W. Wildin, "Temperature and Stress Distributions Produced in Long Circular Cylinders Cooled by Emission of Thermal Radiation," Report No. ME-19, Bureau of Engineering Research, the University of New Mexico, Albuquerque, New Mexico, 1965 (Master's Thesis, Mechanical Engineering Department, UNM, October 1965).

4. R. S. Pritchard, "On a Numerical Technique for Elastic Wave Propagation," Report No. ME-32, Bureau of Engineering Research, the University of New Mexico, Albuquerque, New Mexico, December, 1967.

5. M. W. Wildin and R. S. Pritchard, "Transient Strain and Temperature Distributions in Long Circular Cylinders Cooled by Emission of Thermal Radiation," Experimental Mechanics, Vol. 8, No. 6, June, 1968.

6. R. S. Pritchard and F. D. Ju, "Three Dimensional Elastic Wave Propagation in Bodies of Revolution," Report No. E-45(69), Bureau of Engineering Research, the University of New Mexico, Albuquerque, New Mexico, August, 1970 (Ph.D. Dissertation, Mechanical Engineering Department, UNM, August 1970; also published as Air Force Office of Scientific Research Scientific Report, AFOSR-70-2406TR).

7. R. S. Pritchard, "Numerical Approximations to the Deformation of a Continuum," Eric H. Wang Civil Engineering Research Facility technical report to Air Force Weapons Laboratory, Albuquerque, New Mexico, November 1970.

8. R. O. Davis, W. H. Chown, P. N. Sonnenburg and R. S. Pritchard, "Theoretical Calculations for DIHEST Improvement Program -- Event I-A," Air Force Weapons Laboratory AFWL-TR-71-123, Kirtland Air Force Base, New Mexico, August 1971.

DR. ROBERT S. PRITCHARD (Cont.)

Senior Research Scientist
Manager, Geomechanics Department

Publications: (Cont.)

9. R. S. Pritchard, "Time History Plot Package for AFTON 2A Code," Eric H. Wang Civil Engineering Research Facility technical note to Air Force Weapons Laboratory, Albuquerque, New Mexico, November 1971.

10. R. S. Pritchard and J. J. Blake, "Motion-Picture Plot Package for AFTON 2A Code," Eric H. Wang Civil Engineering Research Facility technical report to Air Force Weapons Laboratory, Albuquerque, New Mexico, February 1972.

11. R. S. Pritchard, "Generator for AFTON 2A Code," Eric H. Wang Civil Engineering Research Facility technical report to Air Force Weapons Laboratory, Albuquerque, New Mexico, March 1972.

12. R. S. Pritchard, "Stability Analysis of AFTON Codes," Eric H. Wang Civil Engineering Research Facility technical report to Air Force Weapons Laboratory, October 1972.

13. R. S. Pritchard and H. A. B. Rae, "Dispersion Curves for a Two-Layer Elastic Half-Space," Eric H. Wang Civil Engineering Research Facility technical report to Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, 1973.

14. W. T. Ristau and R. S. Pritchard, "Computer Code for Complex Chemical Equilibrium Studies at Elevated Temperatures and Pressures," Eric H. Wang Civil Engineering Research Facility technical report to Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, 1973.

15. M. D. Coon, G. A. Maykut, R. S. Pritchard, D. A. Rothrock and A. S. Thorndike, "Modeling the Pack Ice as an Elastic-Plastic Material?" AIDJEX Bulletin No. 24, University of Washington, Seattle, Washington, pp. 1-106, 1974.

16. M. D. Coon and R. S. Pritchard, "Application of an Elastic-Plastic Model of Arctic Pack Ice," The Coast and Shelf of the Beaufort Sea, eds. J. C. Reed and J. E. Sater, The Arctic Institute of North America, Arlington, VA, pp. 173-193, 1974.

17. R.S. Pritchard, "What? Strain? What Strain?" AIDJEX Bulletin No. 26, University of Washington, Seattle, Washington, pp. 59-74, 1974.

DR. ROBERT S. PRITCHARD (Cont.)

Senior Research Scientist
Manager, Geomechanics Department

Publications: (Cent.)

18. R. S. Pritchard and R. Colony, "One-Dimensional Difference Scheme for an Elastic-Plastic Sea Ice Model," Computational Methods in Nonlinear Mechanics, the Texas Inst. for Computational Mechanics, Austin, Texas, pp. 735-744, 1974. Also in AIDJEX Bulletin No. 26, University of Washington, Seattle, Washington, pp. 48-58, 1974.

19. R. S. Pritchard, "Elastic Strain in the AIDJEX Sea Ice Model," AIDJEX Bulletin No. 27, University of Washington, Seattle, Washington, pp. 45-62, 1974.

20. R. S. Pritchard, "An Elastic-Plastic Constitutive Law for Sea Ice," Transactions of the ASME, Vol. 97, Journal of Applied Mechanics, Vol. 42, Series E, No. 2, pp. 379-384, June 1975.

21. R. Colony and R. S. Pritchard, "Integration of Elastic-Plastic Constitutive Laws," AIDJEX Bulletin No. 30, University of Washington, Seattle, Washington, pp. 55 80, 1975.

22. R. S. Pritchard, "A Difference Approximation to the Momentum Equation," AIDJEX Bulletin No. 30, University of Washington, Seattle, Washington, pp. 81-93, 1975.

23. R. Colony and R. S. Pritchard, "Integration Scheme for an Elastic-Plastic Sea Ice Model," Proceedings of the 12th Annual Meeting of the Society of Engineering Science, the University of Texas at Austin, Texas, 1975.

24. R. T. Schwaegler and R. S. Pritchard, "Applications of the AIDJEX Ice Model," in Proceedings of the Third International Conference on Port and Ocean Engineering Under Arctic Conditions, Vol. 1, Institute of Marine Science, University of Alaska, Fairbanks, Alaska, pp. 513-526; reprinted in AIDJEX Bulletin No. 31, University of Washington, Seattle, Washington, pp. 137- 150, 1976.

25. R. S. Pritchard and R. Colony, "A Difference Scheme for the AIDJEX Sea Ice Model," in Numerical-Methods in Geomechanics, Vol. II, ed. C. S. Desai, American Society of Civil Engineers, New York, 1976, pp. 1194-1209; reprinted in AIDJEX Bulletin No. 31, University of Washington, Seattle, Washington, pp. 188-203, September 1975.

DR. ROBERT S. PRITCHARD (Cont.)

Senior Research Scientist
Manager, Geomechanics Department

Publications: (Cont.)

26. M. D. Coon, R. Colony, R. S. Pritchard and D. A. Rothrock, "Calculations to Test a Pack Ice Model," in Numerical Methods in Geomechanics, Vol. II, ed. C. S. Desai, American Society of Civil Engineers, New York, 1976, pp. 1210-1227; reprinted in AIDJEX Bulletin No. 31, University of Washington, Seattle, Washington, pp. 170-187, September 1976.

27. R. S. Pritchard, "An Estimate of the Strength of Arctic Pack Ice," AIDJEX Bulletin No. 34, University of Washington, Seattle, Washington, pp. 94-113, 1976.

28. R. S. Pritchard, M. D. Coon, M. G. McPhee and E. Leavitt, "Winter Ice Dynamics in the Nearshore Beaufort Sea," Appendix 3 in Annual Report on contract 03-50-022-67, No. 5 to Outer Continental Shelf Environmental Assessment "Program, April 1, University of Alaska, Fairbanks, Alaska, 1977.

29. M. D. Coon, R. T. Hall and R. S. Pritchard, "Prediction of Arctic Ice Conditions for Operations," in 1977 Offshore Technology Conference Proceedings, Vol. IV, Houston, Texas, pp. 307-314, 1977.

30. R. S. Pritchard, M. D. Coon and M. G. McPhee, "Simulation of Sea Ice During AIDJEX," Transactions of the ASME: Journal of Pressure Vessel Technology, Vol. 99, Series J, No. 3, pp. 491-497, August 1977; preprinted in AIDJEX Bulletin No. 34, University of Washington, Seattle, Washington, pp. 73-93, 1976.

31. R. S. Pritchard, "The Effect of Strength on Simulations of Sea Ice Dynamics," ed. D. B. Muggeridge, in Proceedings of the Fourth International Conference on Port and Ocean Engineering Under Arctic Conditions, Memorial University of Newfoundland, September 26-30, 1977.

32. R. S. Pritchard and M. D. Coon, "A Research Plan to Test the AIDJEX Model as an Ice Forecasting Aid," Annual Report to NOAA/ERL, Boulder, Colorado, on contract 03-6-022-35330, June 30, 1977.

33. R. S. Pritchard, "A Simulation of Near Shore Winter Ice Dynamics in the Beaufort Sea," in Proceedings of a Symposium on Sea Ice Processes and Models, Seattle, Washington, September 6-9, 1977.

DR. ROBERT S. PRITCHARD (Cont.)

Senior Research Scientist
Manager, Geomechanics Department

Publications: (Cont.)

34. R. S. Pritchard and D. R. Thomas, "The Range of Influence of Boundary Parameters in the AIDJEX Model," in Proceedings of a Symposium on Sea Ice Processes and Models, Seattle, Washington, September 6-9, 1977.

35. R. T. Schwaegler and R. S. Pritchard, "AIDJEX Model Response to Axisymmetric Loadings," in Proceedings of a Symposium on Sea Ice Processes and Models, Seattle, Washington, September 6-9, 1977.

36. M. D. Coon and R. S. Pritchard, "Mechanical Energy Considerations in Sea Ice Dynamics," Journal of Glaciology, Vol. 24, No. 90, 1979.

37. Contributor to "Interim Synthesis Report: Beaufort/Chukchi" on Environmental Assessment of the Alaskan Continental Shelf, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Boulder, Colorado, 1978.

38. R. S. Pritchard, "The Effect of the Pack Ice on Land Fast Ice Motion," Parts 1 and 2, Report to AMOCO Production Research Company, Tulsa, Oklahoma, 1978.

39. R. S. Pritchard, "Axisymmetric Tapered Seal Analysis," Flow Technical Memo No. 174, Flow Research Company, Kent, Washington, 1978.

40. D. R. Thomas and R. S. Pritchard, "Oil Movement in the Ice Covered Beaufort and Chukchi Sea," in The Physical Behavior of Oil in the Marine Environment, Proceedings of a workshop at Princeton University, May 8 and 9, 1979. Also in Flow Research Report No. 138, Flow Research Company, Kent, Washington, 1979.

41. D. R. Thomas and R. S. Pritchard, "Beaufort and Chukchi Sea Ice Motion - Part 1. Pack Ice Trajectories," Flow Research Report No. 133, Flow Research Company, Kent, Washington, 1979.

42. R. W. Reimer, R. S. Pritchard and M. D. Coon, "Beaufort and Chukchi Sea Ice Motion - Part 2. Onset of Large Scale Chukchi Sea Ice Breakout," Flow Research Report No. 133, Flow Research Company, Kent, Washington, 1979.

43. R. S. Pritchard, M. D. Coon and D. R. Thomas, "Mechanical Energy Budget in Ice Covered Oceans," Flow Research Report No. 137, Flow Research Company, Kent, Washington, 1979.

DR. ROBERT S. PRITCHARD (Cont.)

Senior Research Scientist
Manager, Geomechanics Department

Publications: (Cont.)

44. M. D. Coon and R. S. Pritchard, "The Transport and Behavior of Oil Spilled In and Under Sea Ice," Annual Report to Outer Continental Shelf Environmental Assessment Program on Research Unit 567, National Oceanic and Atmospheric Administration, Boulder, Colorado, 1979.

45. R. S. Pritchard, R. W. Reimer and M. D. Coon, "Ice Flow through Straits," in Proceedings of POAC79, Vol. 3, Trondheim, Norway, August 13-17, 1979.

46. R. S. Pritchard, "Transport and Behavior of a Prudhoe Bay Oil Spill," in Proceedings of a Workshop on Oil in Ice held in Toronto on October 10-11, 1979 (Sponsored by University of Toronto and CANMAR).

47. R. S. Pritchard and R. W. Reimer, "The Effect of Waterjet Slots on Roller Cutter Performance in Imberg Sandstone," Flow Research Report No. 152 to Bergbau-Forschung, Flow Research Company, Kent, Washington, 1979.

48. R. S. Pritchard, Editor of Sea Ice Processes and Models, Symposium Proceedings, University of Washington Press, Seattle, Washington, 1980.

49. R. S. Pritchard and R. W. Reimer, "Effects of Waterjet Slotting on Roller Cutter Forces," in Proceedings of 21st U.S. Rock Mechanics Symposium, ed. D. Summers, University of Missouri - Rolls, 1980.

50. D. R. Thomas and R. S. Pritchard, "Beaufort Sea Ice Mechanical Energy Budget 1975-76," Flow Research Report No. 165, Flow Research Co., Kent, Washington, 1980.

51. R. Reimer, R. Pritchard and M. Coon, "Consistent Reduction of Ice Thickness Distribution to a Few Categories," Flow Research Report No. 167, Flow Research Company, Kent, Washington, 1980.

52. R. W. Reimer, J. C. Schedvin and R. S. Pritchard, "Ice Motion in the Chukchi Sea," Flow Research Report No. 168, Flow Research Company, Kent, Washington, 1980.

53. Pritchard, R. S., "Mechanical Behavior of Pack Ice," in Mechanicals of Structured Media, Part A, Elsevier, Amsterdam, 1981.

DR. ROBERT S. PRITCHARD (Cont.)

Senior Research Scientist
Manager, Geomechanics Department

Publications: (Cent.)

54. R. S. Pritchard and J. J. Kollé, "Modeling Sea Ice Trajectories for Oil Spill Tracking," Flow Research Report No. 187, Flow Research Co., Kent, Washington, 1981.

55. R. W. Reimer, S. C. Schedvin and R. S. Pritchard, "Chukchi Sea Ice Motion," In Proceedings of POAC81, University' Laval, Quebec, Canada, 1981.

56. R. S. Pritchard and M. D. Coon, "Canadian Beaufort Sea Ice Characterization ," in Proceedings of POAC81, University' Laval, Quebec, Canada, 1981.

57 Thomas, D. R. and R. S. Pritchard, Norton Sound and Bering Sea Ice Motion, 1981: Data Report," Annual Report to Outer Continental Shelf Environmental Assessment Program on Research Unit 567, National Oceanic and Atmospheric Administration, Boulder, Colorado, to appear.

MR. DONALD R. THOMAS

Research Scientist

Home Address:

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Education:

Army Electronics, Ft. Monmouth, New Jersey, and Sandia Base, New Mexico, 1959.
B.S., Mathematics, University of Oregon, 1966.
Statistics and Japanese, Portland State University, 1973.

Experience:

U.S. Army Electronics, 1958 - 1961.

Technician, Institute of Molecular Biology, University of Oregon, Eugene, Oregon, 1963 - 1966.

Programmer, Child Study Clinic, University of Oregon Dental School, Portland, Oregon, 1966 - 1973.

Scientific Programmer, Arctic Ice Dynamics Joint Experiment, Seattle, Washington, 1973 - 1978.

Research Scientist, Flow Research Company, Kent, Washington, 1978 - Present.

Specialization:

Computer programming, statistics, numerical modeling, ice dynamics.

Publications:

1. C. Sanin, B. S. Savara, Q. D. Clarkson and D. R. Thomas, "Prediction of Occlusion by Measurements of the Deciduous Dentition," American Journal of Orthodontics, Vol. 57, No. 6, June 1970.

2. C. Sanin, B. S. Savara, D. R. Thomas and Q. D. Clarkson, "Arc Length of the Dental Arch Estimated by Multiple Regression," Journal of Dental Research, Vol. 49, No. 4, July - August 1970.

3. S. Nakamura, B. S. Savara and D. R. Thomas, "Norms of Size and Annual Increments of the Sphenoid Bone from 4 to 16 Years," The Angle Orthodontist, Vol. 42, No. 1, January 1972.

MR. DONALD R. THOMAS

Research Scientist

Publications: (Cont.)

4. S. Nakamura, B. S. Savara and D. R. Thomas, "Facial Growth of Children with Cleft Lip and/or Palate," Cleft Palate Journal, Vol. 9, No. 2, April 1972.

5. D. Thomas, "Snow Anchors," OFF BELAY, June 1972, No. 3.

6. J. F. Nye and D. R. Thomas, "The Use of Satellite Photographs to Give the Movement and Deformation of Sea Ice," AIDJEX Bulletin No. 27, University of Washington, Seattle, Washington, November 1974.

7. R. S. Pritchard and D. R. Thomas, "Response of Sea Ice to One-Dimensional Driving Forces and Boundary Perturbations," AIDJEX Bulletin No. 38, University of Washington, Seattle, Washington, March 1978.

8. D. R. Thomas and R. S. Pritchard, "Beaufort and Chukchi Sea Ice Motion - Part 1. Pack Ice Trajectories," Environmental Assessment of the Alaskan Continental Shelf, Annual reports of Principal Investigators, Vol. VIII, Transport, 1979. Also published as Flow Research Report No. 133, Flow Research Company, Kent, Washington, March 1979.

9. R. S. Pritchard, M. D. Coon and D. R. Thomas, "Modeling the Mechanical Energy Budget of the Beaufort Sea Ice Cover," Flow Research Report No. 137R, Flow Research Company, Kent, Washington, 1979.

10. D. R. Thomas and R. S. Pritchard, "Oil Movement in the Ice Covered Beaufort and Chukchi Sea," in The Physical Behavior of Oil in the Marine Environment, Proceedings of a workshop held at Princeton University, May 8 and 9, 1979. Also in Flow Research Report No. 138, Flow Research Company, Kent, Washington, 1979.

11. R. S. Pritchard and D. R. Thomas, "The Range of Influence of Boundary Parameters in the AIDJEX Model," in Sea Ice Processes and Models (cd. R. S. Pritchard), University of Washington Press, Seattle, Washington, 1980.

12. D. R. Thomas and R. S. Pritchard, "Beaufort Sea Ice Mechanical Energy Budget 1975-76," Flow Research Report No. 165, Flow Research Company, Kent, Washington, 1980.

13. D. R. Thomas, "Behavior of Oil Spills Under Sea Ice-Prudhoe Bay," Flow Research Report No. 175, Flow Research Company, Kent, Washington, 1980.

MR. DONALD R. THOMAS

Research Scientist

Publications: (Cont.)

14 . D. R. Thomas, "Prudhoe Bay Oil Spill Scenarios," Flow Research Report No. 176, Flow Research Company, Kent, Washington, 1980.

15. D. R. Thomas, "Harrison Bay Sea Ice Conditions Relating to Oil Spills." Flow Research Report No. 189, Flow Research Company, Kent, Washington, 1981.

16. Thomas, D. R. and R. S. Pritchard, Norton Sound and Bering Sea Ice Motion, 1981: Data Report," Annual Report to Outer Continental Shelf Environmental Assessment Program on Research Unit 567, National Oceanic and Atmospheric Administration, Boulder, Colorado, to appear.

RESUME (March 1981)

NAME : Miles Gordon McPhee

BORN : 9 August 1946, Yakima, Washington

MARTIAL STATUS: Married, three children

EDUCATION :

B. S., 1068 Stanford University, Civil Engineering (with distinction).
Ph.D., 1974 [university of Washington, Geophysical Fluid Dynamics

POST GRADUATE APPOINTMENTS AND EMPLOYMENT:

Engineer, Anderson Bridge Co., Kirland, WA, (1968-1969).

Office Engineer, Guy F. Atkinson Co., Highway Construction Division, South San Francisco, CA., (1969-1970).

Research Assistant, Geophysics program University of Washington, Seattle, WA., (1971–1974).

Research Scientist responsible for oceanic boundary layer studies, AIDJEX, University of Washington, (1974-1978).

Research Geophysicist, Cold Regions Research and Engineering Laboratory (CRREL), (1978-present).

PROFESSIONAL ACTIVITIES:

Organizations

Member, American Geophysical Union
Sponsor, Union of Concerned Scientists

Invited Lectures

University of Miami, 1976
North Carolina State University, 1976
Naval Postgraduate School, 1977
Oregon State University, 1977
Woods Hole Oceanographic Institution, 1978

Workshops and Institutes, Invited Participation

NATO Advanced Study Institute, "Modeling and Prediction of the Upper Layers of the Ocean", Urbino, Italy, September 1975.
FGGE Polar Workshop, Boulder, January, 1976, Rapporteur
NOAA Ice Conference, Seattle, May, 1976
Ocean Forecasting Workshop, Monterey, June, 1976

Workshops and Institutes, Invited Participation (Cent)

ONR "MUMMERS" Workshop, Monterey, July, 1976, Rapporteur, Meteorology/ice dynamics panel.
Marine Sciences Board, Panel on Polar Ocean Engineering, Seattle, February, 1978.
Workshop on Eastern Arctic Research, Copenhagen, January, 1979.
Workshop on the Seasonal Sea Ice Zone, Monterey, February, 1979, Authored review paper for Oceanography Panel.
NASA Cryosphere Workshop, Greenbelt, MD, September, 1979, Chairman, Sea Ice/Oceanography Panel.
European Basin Experiment (EUBEX) Workshop, Seattle, November, 1979, Elected to EUBEX Planning Committee.

PUBLICATIONS:

1972 McPhee, M.G. and J.D. Smith. Flow in the vicinity of a small pressure ridge keel. (abstract) *EOS, Transactions of the American Geophysical Union, 53*, p. 1011.

1974 McPhee, M.G. Turbulent and mean structures of flow in the boundary layer under pack ice, (abstract). *EOS, Transactions of the American Geophysical Union, 55*, p. 322.

McPhee, M.G., An experimental investigation of the boundary layer under pack ice. Ph.D. Thesis, Geophysics Program; also *Technical Report M75-14*, Department of Oceanography, University of Washington, Seattle, WA 164 pp.

1975 McPhee, M.G. and J.D. Smith, Measurements of the turbulent boundary layer under pack ice. *AIDJEX Bulletin, No. 28.*, University of Washington, Seattle, WA pp. 49-92.

McPhee, M.G., Ice-ocean momentum transfer for the AIDJEX ice model, *AIDJEX Bulletin No.* 29, University of Washington, Seattle, WA pp. 93-111.

McPhee, M.G., The effect of ice motion on the mixed layer under arctic pack ice. *AIDJEX Bulletin, No. 30,* pp. 1-27.

1976 McPhee, M.G., A simple model for inertial oscillations in a combined sea ice-upper ocean system, (abstract). *Bulletin of the American Meteorological Society,* 57, p. 155.

Pritchard, R.S., M. D. Coon, and M.G. McPhee, Simulation of sea ice dynamics during AIDJEX. *AIDJEX Bulletin, No. 34,* pp. 73-93.

McPhee, M.G. and J.D. Smith, Measurements of the turbulent boundary layer under pack ice. *Journal of Physical Oceanography, 6, No. 5,* Sept. *1976,* pp. *969-711* (modified version of 1975 AIDJEX Bulletin article).

PUBLICATIONS (Cent)

1976 McPhee, M.G., Water stress sub-model for the AIDJEX model. *proceeding of the Third International conference on Port and Ocean Engineering Under Arctic Conditions,* 11-15 August, 1975, Fairbanks, Alaska. pp. 495-508.

1977 McPhee, M.G., Upper ocean current measurements at manned drift stations in the Arctic, (Abstract). *EOS, Transactions of the American Geophysical Union,* 58, p. 164.

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6. Forms

The forms listed below are included on the following pages:

a. Property Inventory Form (CD-281)
b. Digital Data Tracing Form
c. Data Submission and Products Schedule
d. Milestone Chart
e. Proposed OCSEAP Budget
f. Contract Pricing Proposal Form (Federal Option Form 60)

FORM CD-281
(10-72)
PRESCRIBED BY
HANDBOOK FOR SUPPLY
MANAGEMENT DAO 208-0

U.S. DEPARTMENT OF COMMERCE

DATE OF REPORT	CONTRACT NUMBER
Sept. 1981	03-78-B01-61

NAME AND ADDRESS OF CONTRACTOR (Type or print)
Flow Industries, Inc.
21414 - 68th Avenue South
Kent WA 98031

REPORT OF GOVERNMENT PROPERTY IN POSSESSION OF CONTRACTOR

(See DOC Manual for Control of Government Property by Contractors)

This report covers ☐ expendable ☐ non-expendable property

NAME AND TITLE OF AUTHORIZED REPRESENTATIVE
M. Chandra
Contract Administrator

SIGNATURE
M. Chandra

LIST BELOW EACH ITEM OF GOVERNMENT PROPERTY

GOVERNMENT ID NO. AND FSN	DESCRIPTION OF ITEM	MFR.	MFR. SERIAL NOS.	QUANTITY	CONDITION	LOCATION	COST	DATE RECEIVED
	None Acquired Under Contract							

DIGITAL DATA TRACKING FORM

RU NUMBER 567

PI NAME R.S. Pritchard/D.R. Thomas

FILE TYPE	FILE ID.	PLATFORM	SURVEY START DA/MO/YR	SURVEY END DA/MO/YR	EXPECTED SUBMISSION DATE DA/MO/YR

DATA SUBMISSION AND PRODUCTS SCHEDULE

Data Type (i.e. Intertidal, Benthic Organisms, etc.)	Media (Cards, coding sheets, tapes, disks)	Estimated Volume (Volume of processed data)	OCSEAP format (If known)	Processing and Formating done by Project (Yes or No)	Collection Period (Month/Year to Month/Year)	Submission (Month/Year)

MILESTONE CHART

O Planned Completion Date

X - Actual Completion Date
(to be used for updates)

RU # 567 **PI:** R.S. Pritchard/D. R. Thomas

Major Milestones: Reporting, data management and other significant contractual requirements; periods of field work; workshops; etc.

	1981			1982											
MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1. Review Previous Winter Transport Cal.	----	-----	. 0												
2. Produce Oil Spill Trajectories			----	-----	-----	-----	-----	-----	-----	-----	- 0				
3. Synthesize Oil Spill Scenario										---	-----	-----	-----	-----	-0
Annual Report							0								
Ice Trajectory Modeling Report												0			
Synthesis Report Draft														0	
Attend Synthesis Meeting														0	
Final Report															0

Bid Date: 9/81

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget
Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO OF PAGES 1

NAME OF OFFEROR: Flow Industries, Inc.

HOME OFFICE ADDRESS: 21414 - 68th Avenue South, Kent WA 98031

SUPPLIES AND/OR SERVICES TO BE FURNISHED: FRC Prop. No. 8214 entitled "The Transport and Behavior of Oil Spilled In and Under Sea Ice" Period of Support: 'Sept. 1981 - Dec. 1982

DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Flow Research Company

TOTAL AMOUNT OF PROPOSAL: $ 100,000

GOV'T SOLICITATION NO:

DETAIL DESCRIPTION OF COST ELEMENTS

1. DIRECT MATERIAL (Itemize on Exhibit A)	EST COST ($)	TOTAL EST COST	REFERENCE
a. PURCHASED PARTS			
b. SUBCONTRACTED ITEMS			
c. OTHER—(1) RAW MATERIAL			
(2) YOUR STANDARD COMMERCIAL ITEMS			
(3) INTERDIVISIONAL TRANSFERS (At other than cost)			
TOTAL DIRECT MATERIAL		-0-	
2. MATERIAL OVERHEAD (Rate % X $ base)		-0-	

3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE / HOUR	EST COST ($)	TOTAL EST COST
Dr. R. S. Pritchard	320	25.84	8,269	
Mr. D. R. Thomas	480	17.30	8,347	
Research Scientist	240	15.43	3,702	
Computer Programmer	320	8.00	2,560	
TOTAL DIRECT LABOR				22,878

4. LABOR OVERHEAD (Specify Department or Cost Center)	OH RATE	X BASE =	EST COST ($)	TOTAL EST COST
	85%	22,878	19,446	
TOTAL LABOR OVERHEAD				19,446

5. SPECIAL TESTING (Including field work at Government installations)	EST COST ($)	TOTAL EST COST
TOTAL SPECIAL TESTING		-0-
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)		-0-

7. TRAVEL (If direct charge) (Give details on attached Schedule)	EST COST ($)	TOTAL EST COST
a. TRANSPORTATION	1,995	
b. PER DIEM OR SUBSISTENCE	2,025	
TOTAL TRAVEL		4,020

8. CONSULTANTS (Identify—purpose—rate)	EST COST ($)	TOTAL EST COST
Dr. Miles McPhee		
30 days @ $250/day	7,500	
TOTAL CONSULTANTS		7,500

	TOTAL EST COST
9. OTHER DIRECT COSTS (Itemize on Exhibit A)	19,470
10. TOTAL DIRECT COST AND OVERHEAD	73,314
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate 24 % of cost element Nos. 10)	17,595
12. ROYALTIES	-0-
13. TOTAL ESTIMATED COST	90,909
14. FEE OR PROFIT	9,091
15. TOTAL ESTIMATED COST AND FEE OR PROFIT	100,000

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to (Describe RFP, etc.)

Requesting continuation of contract No. 03-78-B01-61

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Dr. Ken Touryan, Senior Vice President and General Manager	K. J. Touryan

NAME OF FIRM	DATE OF SUBMISSION
Flow Research Company, a division of Flow Industries, Inc.	9/9/81

EXHIBIT A-SUPPORTING SCHEDULE (Specify. If more space is needed, use reverse)

COST EL NO.	ITEM DESCRIPTION (See footnote 5)	EST COST (s)
7.	Travel:	
	3 round trip coach airfare Sea/Fairbanks/Sea	1,995
	Subsistence: 15 days @ $135/day	2,025
	Total	4,020
9.	Other Direct Costs:	
	. Fringe Benefits	7,320
	. State Business Tax	1,000
	. Technical Services 150 hours @ $21/ hour	3,150
	. PRIME Computer @ $210/hour daytime, $35/hour off-time	7,500
	. Data Retrieval from World Data Center-A and NODC	500
	Total	19,470

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO (If yes, identify below.)

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, 815 Airport Way S., Seattle WA 98134	(206) 442-4770

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [ ] NO (If yes, identify on reverse or separate page)

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[X] YES [ ] NO (If yes, identify.): [ ] ADVANCE PAYMENTS [X] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT (Or, do you hold any independently financed (IR&D) projects) FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [ ] NO (If yes, identify.):

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO (If no, explain on reverse or separate page)

See Reverse for Instructions and Footnotes

OPTIONAL FORM 60 (10-71)

PROPOSED RESEARCH UNIT BUDGET

A	DIRECT LABOR :	Hours	Rate/Hour	Estimated Cost	
A 1	Employee (s) :				
	R. S. Pritchard (Dr.)	320	25.84	8,269	
	D. R. Thomas	480	17.39	8,347	
	Research Scientist	240	15.43	3,702	
	Computer Programmer	320	8.00	2,560	
				Total	22,878
A 2	Benefits:	%	X Base =		
		32%	22,878	7,321	
				Total	7,321
A 3	Overhead:	%	X Base =		
		85%	22,878	19,446	
				Total	19,446
				TOTAL FOR A	49,645

B	OTHER DIRECT COSTS: (Itemize Travel & Per Diem)	Estimated Cost	
B 1	Travel: (for field trips).		
	3 Rnd Trip Coach Airfare Sea/Fairbanks/Sea	1,995	
	Subsistence. 15 days @ $135/day	2,025	
		Total	4,020
B 2	Transport of Equipment & Supplies:	Estimated Cost	
		Total	-0-
B 3	Rent: (Space & Equipment)	Estimated Cost	
		Total	--
B 4	Utilities: (e.g., Data Lines)	Estimated Cost	
		Total	--
B 5	Printing & Reproduction:	Estimated Cost	
		Total	--
B6a	Data Processing (In Required Format):	Estimated Cost	
	Data Retrieval from World Data Center- and NODC	500	
		Total	500
B6b	Data Processing (NOAA Provided) (Do Not Include) (In Total)	Estimated Cost	
B7a	Logistics (Aircraft):	Estimated Cost	
B7b	Logistics (Helicopter):	Estimated Cost	
B7c	Logistics (Ship/Boat) :	Estimated Cost	
		Total	-0-

B	OTHER DIRECT COSTS: (Continued)	Estimated Cost	
B 8	Logistics (NOAA Provided) (Do Not Include in Total)		
B 9	~~Subcontracts:~~ Consultants:	Estimated Cost	
	Dr. Miles McPhee 30 days @ $250/day	7,500	
		Total	7,500
B10	Inhouse Services: (e.g., Drafting)	Estimated Cost	
	Technical Services 150 hours @ $21/hour	3,150	
	PRIME Computer @ $210/hour	7,500	
		Total	10,650
B11	Expendable Supplies:	Estimated Cost	
		Total	-0-
B12	Non-Expendable Equipment:	Estimated Cost	
		Total	-0-
B13	~~ADP Equipment:~~ Other Misc. Costs	Estimated Cost	
	State Business Tax	1,000	
		Total	1,000
		TOTAL FOR B	23,670
C	INDIRECT COSTS: (e.g., Fees—Please Specify)	Estimated Cost	
	General and Administrative Expense	17,595	
	Fee	9,091	
		TOTAL FOR C	26,686
		PROPOSED RESEARCH UNIT BUDGET TOTAL	100,000

D REMARKS:

COVER SHEET FORMAT

Proposal/Revision Date: 9/23/81

TO: National Oceanic and Atmospheric Administration
OMPA/OCSEAP
P.O. Box 1808
Juneau, AK 99802

Contract #: 03-78-B01-61

NOAA Project #:

Institution ID#: FRC Prop. 8217

RECEIVED
SEP 28 1981
PROPOSAL
Office of Marine Pollution Assessment
Alaska Office

Research Unit Number 567

TITLE: The Transport and Behavior of Oil Spilled In and Under Sea Ice

Cost of Proposal: $60,000
(If joint proposal, show cost for each institution; if more than one year, show cost for each year (SEPARATE BUDGET SHEETS ALSO REQUIRED).

Lease Areas Chukchi Sea 70 %
Navarin Basin 30 %

Period of Proposal: October 81 - November 82

PRINCIPAL INVESTIGATOR(S):

Name Robert S. Pritchard Donald R. Thomas.
Signature
Address 21414-68th Avenue South, Kent, WA 98031
Telephone Number (206) 872-8500

Date

FTS: 9-23-81

INSTITUTION (include Department, if appropriate)

Flow Research Company, A Division of Flow Industries, Inc.

REQUIRED INSTITUTION APPROVAL:

Name K. J. Touryan
Signature R.J.
Position Sr. Vice President, Gen. Mgr, Flow Research
Address 21414-68th Avenue South, Kent, WA 98031
Telephone Number

Date 9/22/81

INSTITUTION FINANCIAL OFFICER:

Name: R. M. Haines
Signature
Position Vice President, Finance & Administration
Address Avenue South, Kent, WA
Telephone Number (206) 872-8500

Date 9-23-81

2. Qualifications of Principal Investigators

Dr. R. S. Pritchard, a senior research scientist and manager of the Geomechanics Department at Flow Research Company (FRC), is an experienced investigator in the study of polar air-ice-sea interaction problems, especially the dynamic behavior of sea ice. His Arctic experience began with the AIDJEX project in 1973, for which he served as a co-principal investigator. Dr. Pritchard has also been a principal investigator on OCSEAP projects since 1976, including several modeling efforts and buoy deployment programs in the Chukchi Sea and Norton Sound. He is one of the scientists primarily responsible for the development of the AIDJEX sea ice dynamics model, and his modeling experience will provide the guidance needed to understand the behavior of the Beaufort Sea ice cover. Dr. Pritchard is an internationally known researcher who has authored or co-authored nearly 60 publications.

Mr. D. R. Thomas, research scientist in the Geomechanics Department at FRC, brings both a modeling background and field experience to the team. Mr. Thomas is another former AIDJEX staff member, having worked on that project from 1973 until joining FRC in 1978. He is a computing specialist with a strong background in statistics and data processing. Mr. Thomas has been an important investigator in previous OCSEAP studies. Recently, his synthesis and development of scenarios relating to the fate and behavior of oil spilled in Prudhoe Bay has received widespread acceptance by Arctic investigators. Mr. Thomas provides a balance of theoretical and field experience with his understanding of the important portions of this problem.

Flow Research Company is committed to the growth of its Arctic Research program. This commitment began in 1978 with the hiring of the two principal investigators assigned to this project. Since that time, Dr. J. J. Kollé, a fracture mechanics specialist who has taken part in the OCSEAP buoy deployment in Norton Sound, has joined the Geomechanics staff. Other FRC staff members have also been involved with this ongoing research project for OCSEAP, including Dr. J. C. Schedvin, an oceanographer who has become familiar with the ocean current patterns in the Chukchi and Beaufort Seas. These scientists are now an integral part of the research staff at Flow Research Company.

3. Technical Proposal

I. Title: The Transport and Behavior of Oil Spilled In and Under Sea Ice
Research Unit Number: 567
Contract Number: 03-78-B01-61
Proposed Dates of Contract: October 1, 1981 through November 30, 1982

II. Principal Investigators

R. S. Pritchard, Sr. Research Scientist and Manager
Geomechanics Department
Flow Research Company
D. R. Thomas, Research Scientist
Geomechanics Department
Flow Research Company

III. Proposed RU Budget

A. Total Cost: $60,000 (see Item C)

B. Percentage distribution of total by lease area:

Chukchi Sea 70%
Navarin Basin 30%

C. The technical portion of this proposal describes the work this RU will do during FY82. That work has been budgeted at $160,000. Of this amount, $100,000 has already been received from OCSEAP by Flow Research Company as supplemental funds for FY81 so that we could purchase the buoys in a time frame which allows us to complete the described technical work. Therefore, this proposal only requests the remaining $60,000 which is necessary for buoy deployment, data processing and interpretation.

IV. Background

The sea ice motion in the Chukchi and Bering Seas is an important aspect of possible pollution problems in the biologically productive Bering Sea. Oil spills which occur in winter in the Arctic will become incorporated into the ice cover, not to be released from the ice until the following spring (see Thomas, 1980). Thus, wintertime ice motion and pollution transport is an important problem.

A previous study by this research unit (Reimer et al., 1980 and 1981) examined the sea ice breakout phenomenon from the Chukchi to the Bering Sea. Results of this study showed that breakout is associated with reversals of the long-term mean northward currents which periodically occur in the Bering Strait (Coachman and Aagaard, 1981). Model studies showed that ocean currents are the important driving force during breakout. The model used in that study was an idealized and simpler form of the ice model developed during AIDJEX (Coon, 1980) with modifications described by Pritchard (1981). This model did not consider all the forces acting upon the ice or the feedback mechanisms whereby ice motion and deformation influences ice strength and thus future ice motion. This omission was partly due to the absence of an adequate data set to drive the model and check the results.

Previous buoy studies of ice drift in the Chukchi Sea have been described by Pritchard (1978) and Colony (1979). These studies were done in a limited manner to answer specific questions. While the data from those studies has been useful and will still be useful for providing information on the annual variation of ice motion in the Chukchi Sea, several shortcomings may be noted in those data. First, the buoys were deployed in March 1977 and March 1978. Thus, no data exists for the period between freezeup in October or November and March. This period may be particularly important since the ice is thinner and weaker during early winter and motions may be larger. Second, only ice drift data were obtained during those studies. A full understanding of sea ice motion requires the concurrent collection of atmospheric and oceanic data as well as data on ice conditions and motion.

An ice drift study has also been conducted in the Norton Sound/ Bering Sea region (Thomas and Pritchard, 1981). Buoys were deployed on the ice in Norton Sound as soon as possible after freezeup and tracked until ice melt sank the buoys. As an illustrative example of the importance of the Bering Strait connection between the Bering and Chukchi Seas, one of the Norton Sound buoys ended up in the mid-Chukchi Sea.

V. Ojectives

The objectives for this research unit during FY82 are:

1) To determine the large-scale ice movement and ice trajectories in the Bering and Chukchi Seas.
2) To determine the relationship of ice motion to the winds and currents.

VI. Strategy and Approach

The objectives of this proposed work, to determine large-scale ice motions in the Bering and Chukchi Seas and to determine the effects on ice motion of winds and other factors will be met by deploying an array of buoys with appropriate atmospheric and oceanic sensors. The results will be quite useful in a qualitative sense and, in fact, this data gathering and qualitative analysis is a necessary first step for any more complex and quantitative descriptions of the ice cover. The second step requires the use of a mathematical model of the physical properties and processes of the ice cover, atmosphere and ocean. Such a model allows one to more exactly quantify the effects of driving forces and ice properties on the ice motion, as well as to observe the interactions and feedback which take place in a real ice cover.

Because of funding limitations, we are not proposing to do model studies during the FY82 contract period, but we feel that it is extremely important that all data collected during the course of the proposed work be suitable for use in model studies which can be done later. We have planned the buoy deployments (location, time of deployment, and sensors on each buoy) to complement other data sources and provide a qualitative answer to the questions implicit in the stated objectives, but we have also kept in mind the necessity of providing a data set that is complete for use in modeling studies.

The buoys deployed in this project will all be located in Hope Basin and the eastern Chukchi Sea. Six buoys will be deployed at two different times. The first deployment will be early in the ice season (early December) when three TAD(A) position only buoys will be air dropped (see Figure 1). These buoys must be air dropped because of the lack of daylight and unsafe ice conditions. They will measure location only, except one will also have a barometer. These buoys will give us our first data on early season ice motion in the Chukchi Sea. The previous buoy data for this region begins'in March (see Pritchard, 1978, and Colony, 1979), except for one AIDJEX buoy which drifted around Pt. Barrow during the winter of 1975-76 (Reimer et al., 1980) . We feel that it is important to get this early season drift data since the ice is thinnest and weakest early in the ice season and thus ice motions may be greatest. The second deployment will be in early February when three ADAP buoys with current meters (one will also have a barometer) will be deployed (see Figure Z). February is the earliest date that these buoys can be deployed, since the ice conditions by then are suitable for landing a small plane and sufficient daylight has returned for visibility.

Rather than collect wind data directly by using anemometers on the buoys, we will compute large-scale geostrophic winds using atmospheric pressure data. When based upon adequate data, the computed winds are more representative of the winds felt by the ice on scales useful for analysis than are the measured local surface winds. The presence of the FGGE buoy array provides useful pressure data for computing geostrophic winds. No FGGE buoys are located in the Chukchi Sea at this time, however, so two buoys deployed by us (allowing for the possibility of one failure) will contain barometers. This will allow us to fill the gap between land-based atmospheric pressure measurements and the FGGE array and to compute accurate geostrophic winds for the region. These two buoys will be deployed furthest to the west to provide the most information on large-scale pressure gradients.

The other four buoys will be deployed nearer the Alaskan Coast where high-speed alongshore ocean currents flow. These currents have been determined to be the dominant factor for ice motion along the coast and through the Bering Strait. One of these four buoys will be placed in Hope Basin where no ice drift data exists at present.

Three of the buoys will be deployed with current meters. One will be located in Hope Basin, one in the high-speed current region near Pt. Franklin, and one will be to the west near Herold Shoal and the U.S./U.S.S.R. convention line. The current meters will be suspended 10 meters below the ice and will represent the local currents felt by the ice. The buoys will be deployed in the vicinity of the bottom-moored deep current meters that are being deployed by RU#541. Initially, then, we will have some information on the vertical structure of the currents, although ice motion will cause this information to decrease later in the ice season.

The three buoys with current meters will be deployed in early February when ice conditions are suitable for landing a small plane, and when sufficient daylight has returned for visibility. This is the earliest date by which these buoys can be deployed with any safety.

The atmospheric pressure data obtained by us will be furnished to the Polar Science Center at the University of Washington to be included in their analysis of the FGGE buoy data. As soon as possible, we will obtain the surface pressure analysis from which we can compute geostrophic wind fields.

The current data obtained by us will be filtered to remove tidal and other high-frequency currents. From this data, plus the bottom topography, we will compute tentative long-term ocean current fields. Eventually, we would like to incorporate the bottom-moored current meter data being obtained by RU#541, but this is unlikely during this contract period since those meters will not be recovered until September 1982.

The ice motion data will also be filtered to obtain mean daily values of ice drift. This data will be presented as time histories and as monthly ice drift fields. If possible, corresponding fields of currents and winds will be presented.

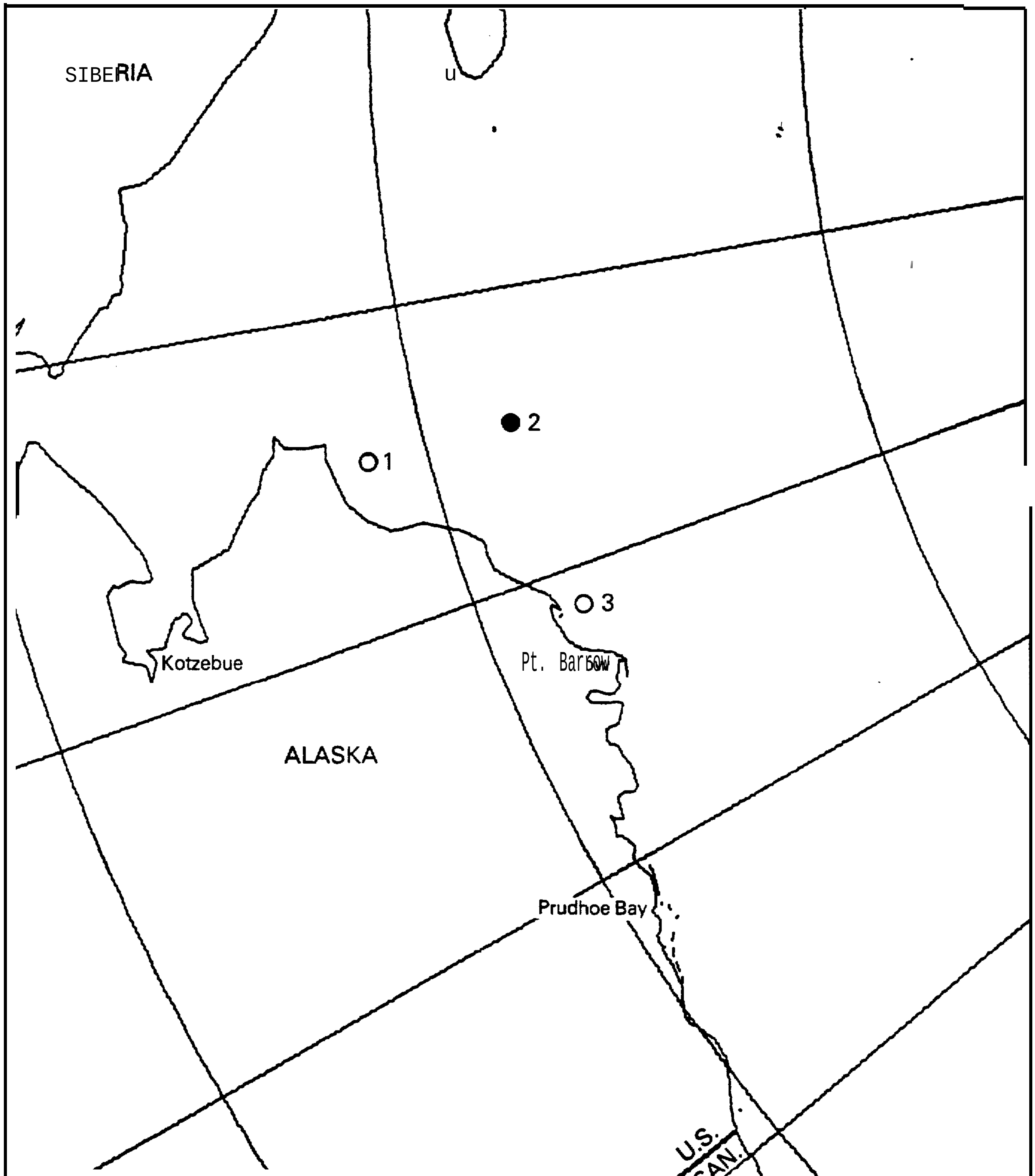

Figure 1. **December 1981 Buoy Deployment. Open Circles Indicate TAD(A) Air Drop Buoys. Solid Circle Indicates TAD(A) Equipped with Barometer. Buoys 1 and 2 and Possibly 3 can be Deployed on One Flight from Kotzebue. If Two Flights are Required, Buoy 3 can be Deployed on the Second Flight**

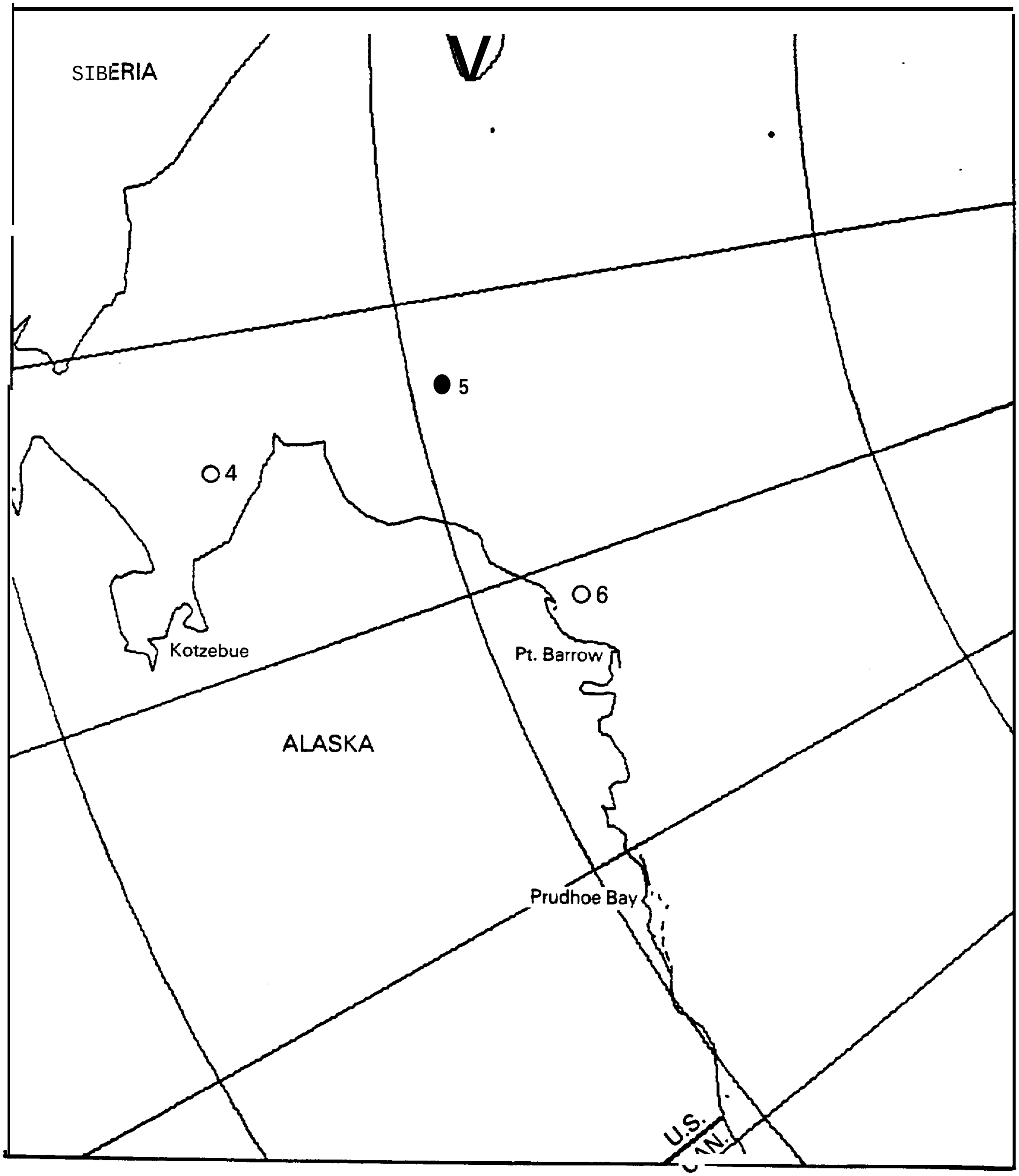

Figure z. February 1982 Buoy Deployment. Open Circles Indicate ADAP Buoys Equipped with Current Meter. Solid Circle Indicates ADAP Buoy with Current Meter and Barometer. Buoy #4 in Hope Basin Can be Deployed by Helicopter from Kotzebue. The Other Two Buoys must be Deployed by Light Plane from Barrow

VII. Deliverable Products

A. Digital Data:

1. The data obtained will be ice motion data presented in terms of buoy location and time; ocean current data in terms of location, time, depth, current speed and current direction; and atmospheric pressure data in terms of location, time and surface pressure.

2. The data buoys are calibrated to strict tolerances by Polar Research Laboratory, Inc., before deployment. Buoy locations are determined by Service ARGOS on the basis of two satellite passes. All data will be plotted and examined for obvious errors.

3. The buoy location data for Norton Sound and the Bering Sea obtained by this RU during FY81 are being submitted to OCSEAP and NODC.

4. Previous buoy location data taken in the Chukchi Sea will be obtained for comparison purposes. Atmosphere pressure data from the FGGE buoy array will also be obtained to develop wind fields for the Chukchi Sea. Atmospheric pressure data for the Bering Sea will be obtained from NCAR.

5. The Data Submission and Products Schedule is included in Section 6 of this proposal package.

B. Narrative Reports

An annual report will be prepared and submitted by April 1, 1982. This report will include a description of the progress to date. We will also incorporate final copies of any individual reports prepared in the prior year.

A report will be prepared by November 1982 describing the data obtained during this experiment. The report will contain summaries of the data in the form of plots of filtered daily values of buoy motion, atmospheric pressure and ocean currents.

C. Visual Data

The final report will contain plots of all data. Filtered daily values will be presented. Atmospheric pressure at buoy locations will be presented as a time history. Ocean currents will be presented as maps of short-term mean currents. Ice motion will be presented as trajectories on maps. These map products will be in Universal Transverse Mercator projections with a scale to be determined jointly by the contract supervisor and the principal investigators.

D. Other Data

Magnetic tape copies of all raw data will be presented to OCSEAP and NODC.

VIII. Milestone Chart

The milestone chart is included in Section 6 of this proposal package.

IX. Logistics Requirements

The logistics required for this project are described on the appropriate forms in section 6 of this proposal package. In addition, we note the following points.

The December 1981 buoy deployment will deploy air drop buoys since conditions in the Chukchi Sea will not be safe for landing on the ice at this time. A Twin Otter is the best plane for this mission because of its range, payload and air drop capability. This mission can be flown from Pt. Barrow or Kotzebue, but we understand that a Twin Otter is more likely to be available in Kotzebue.

For the February 1982 buoy deployments, it is necessary to land on the ice to deploy the current meters. We request a helicopter from Kotzebue to deploy the one buoy with a current meter in Hope Basin. The helicopter provides more choice of site selection in case of ice motion and deformation or open water. For the two most northerly buoy deployments, a Cessna on skis, based at Barrow, seems appropriate due to its range and ice landing capability.

We will coordinate our February 1982 deployment with RU#541 (Dr. Aagaard and Dr. Tripp) so that, if possible, we can share a flight or two with their investigators making oceanographic observations.

X. Anticipated Problems

The major difficulty we expect is unfavorable flying conditions in the Chukchi Sea during the winter. This will cause delays in buoy deployments, but delays of a week or two will not seriously degrade the anticipated data set.

Ice conditions will determine the exact location of all buoys deployed. This will probably not cause any major changes to our plans.

XI. Information Required from Other Investigators

The results of this proposed work will provide the majority of the data required to analyze the relationship between ice motion and winds and ocean currents, but the acquisition of certain other data will greatly enhance the value of the data set.

Obtaining atmospheric pressure data for the Bering and Chukchi Seas is a necessity. These data are the only means of estimating the winds for those areas. The Bering Sea data will be acquired from NCAR; it is based upon NWS atmospheric pressure maps. The Chukchi Sea data will be acquired from the World Data Center-A for Glaciology; it is based upon atmospheric pressure measurements made by FGGE buoys. Due to time limitations, some preliminary FGGE data may need to be obtained through personal contacts at the Polar Science Center, University of Washington.

The ocean current data obtained by RU#541 from bottom moored buoys in the Chukchi Sea between September 1981 and September 1982 would be particularly useful in supplementing our current data. Unfortunately, due to the amount of data processing required after the buoys are recovered in September 1982, these data are unlikely to be available before the end of 1982. However, we see no difficulty in eventually acquiring the data.

We also plan to contact RU#267 to acquire satellite images to illustrate large-scale ice conditions during the course of this project.

XII. Outlook

The data set obtained by the proposed work should be adequate to enable us to gain some understanding of winter and spring ice motions in the Chukchi Sea. Previous OCSEAP-sponsored buoy deployments in the Chukchi Sea (in March 1977 and 1978) will provide additional information on the year-to-year variability of ice motion. The buoys to be deployed in this work will give us our first detailed look at wintertime ice motions in the Chukchi Sea. Furthermore, the ice motion data obtained will be supplemented by concurrent atmospheric pressure data from the FGGE buoy array which, with the addition of barometric pressure measurements made by some of the buoys we will deploy, can be used to accurately calculate the wind fields over the Chukchi Sea. Ocean current data will also be available during this study. The current data will come from current meters on some of the drifting buoys and from bottom moored meters deployed by RU#541.

The data set obtained in this study will be ideal for both driving an ice model and validating the results of such a model. The use of an ice model, such as the one developed by AIDJEX, would be particularly useful in the Chukchi Sea/Bering Strait region for determining likely trajectories of oiled ice. Previous ice drift observations using buoys has shown that ice from Norton Sound and the northern Bering Sea may pass north through the Bering Strait into the central Chukchi Sea. Other buoy motions have shown that ice from the vicinity of Pt. Barrow may be driven far south in the Chukchi Sea. A previous study by this research unit (Reimer et al., 1980 and 1981), using a limited form of the AIDJEX model in which ice strength remained constant, showed that ocean currents are the dominant force in such large southward ice motions. Ice strength was the determining factor in whether large ice motions occur during periods of current reversals, when the normally northward flowing currents reverse and flow south through the straits.

In that study, it was pointed out that a coupled (varying strength) ice model calculation is necessary to determine the effects that deformations, which influence ice strength, will have on ice motion. It was also noted that a finer grid scale (and thus more expensive calculations) would be necessary to study the effect of the Diomede Islands on ice movement through the Bering Strait and for studying ice motion in Hope Basin.

Depending upon the occurrence of a current reversal to the south and Bering Strait ice breakout during the winter of 1981-82, the data set resulting from the work in the present proposal will be ideal for doing the more complete and detailed calculations. It should be noted that current reversals through the Bering Strait usually occur several times each winter.

Due to the cost of buoys and deploying them, the funds available to this RU during FY82 will not allow of the model calculations described above. Those model calculations are important in understanding the ice motions in the Chukchi Sea and Bering Strait. With the understanding resulting from model calculations, it is possible to describe the most likely oiled ice trajectories from a historical wind statistics. The model calculations and oil spill trajectories could be done for an estimated cost of approximately $150,000.

The work described in this proposal does not involve any buoy deployments in the Norton Sound/Bering Sea area. This omission is for two reasons: (1) we feel that a top quality, complete data set for one region (the Chukchi Sea) is more important and useful than two incomplete data sets for two regions, and (2) we have submitted a proposal for joint funding by AOGA and OCSEAP covering the collection of data in the Norton Sound/Bering Sea area. We feel that the acquisition of another year's ice motion data for that region is important and should be accompanied by simultaneous wind and current data. The cost of a full buoy data program for that region is approximately $125,000. The additional analysis of that data, involving the use of a free drift-ice model and the calculations of likely oiled ice trajectories, will require about $50,000.

X111. References

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Reimer, R. W., J. C. Schedvin, and R. S. Pritchard (1981) "Chukchi Sea Ice Motion," in POAC 81, Université Laval, Quebec, pp. 1038-1046.

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Thomas, D. R. and R. S. Pritchard, Norton Sound and Bering Sea Ice Motion, 1981: Data Report, "Annual Report to Outer Continental Shelf Environmental Assessment Program on Research Unit 567, National Oceanic and Atmospheric Administration, Boulder, Colorado, to appear.

XIV. Standard Statements

A. Reports will be submitted in accordance with Section VII-B of the proposal. Each required report will consist of an original, reproducible manuscript and nine copies on 8-1/2 x 11 paper.

B. For all biological research, representative voucher specimens will be preserved and labelled in accordance with OCSEAP Voucher Specimen Policy. Voucher specimens will be shipped to an OCSEAP-designated repository before the expiration date of the contract. Costs for the preparation and delivery of voucher specimens should be included in the project budget.

C. Deliverable products will be submitted to the Alaska Office in the form and format specified in Section VII. Digital data submissions will be accompanied by a Data Documentation Form (NOAA Form 24-13).

D. Within 10 days of the completion of a cruise or other data gathering effort, the PI will submit a ROSCOP data collection inventory form (NOAA Form 24-23) to the OMPA/OCSEAP Alaska Office Data and Information Manager.

E. Within 30 days of the completion of OCSEAP provided logistics support, the PI will provide a field operations report to the OMPA/OCSEAP Operations/Logistics Manager.

F. Title for all non-expendable property purchased with OCSEAP funds remains with BLM/OCSEAP pending disposition at contract' expiration. An inventory of new non-expendable equipment purchased will accompany the narrative reports.' The PI will maintain inventories and record on Form CO-281, "Report of Government Property in Possession of Contractor."

G. The PI and other project staff are prepared to travel to the OMPA/ OCSEAP to discuss the project. Such conferences will be scheduled on dates mutually satisfactory to both parties. In addition, the PI and other project staff will participate in program review or synthesis meetings as requested by OMPA/OCSEAP. It is understood that costs of the travel and per diem for these trips, if not included in the RU budget, will be borne by OCSEAP.

H. All maps will be submitted in Universal Transverse Mercator (UTM) projection at a scale of 1:250,000 or 1:500,000. Other scales or projections may be used after consultation and in agreement with OCSEAP contract supervisor. All maps will also be reduced to 8-1/2 x 11 inches for inclusion in the accompanying reports.

I. The Principal Investigator shall actively lead and supervise the proposed work, and shall take full responsibility for timely completion of all objectives, independent of the percentage of the Principal Investigator's salary requested in the budget.

J. Three (3) copies of all manuscripts prepared for publication or presentation which pertain to technical or scientific material developed under OCSEAP sponsorship, will be submitted to the OMPA/OCSEAP Alaska Office at least sixty (60) days prior to release, for information and for forwarding to BLM. The release of such material within a period of less than sixty days will be made only with prior written consent of the OMPA/OCSEAP Alaska Office. News releases will first be cleared with the Alaska Office. Five copies of the reprints will be submitted to the Alaska Office.

K. All publications and presentations of material developed with OCSEAP funds will acknowledge BLM/OCSEAP sponsorship. The following acknowledgement will be used:

> "This study was funded (wholly or in part) by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, as part of the Outer Continental Shelf Environmental Assessment Program."

4. Proposed RU Budget

The propsed RU budget is detailed on the budget forms included in Section 6 of this proposal package.

The proposed budget is for the amount of $60,000 and covers the cost of deploying buoys and processing the resulting data. Purchase of the buoys is not included since that item is covered by a supplemental FY81 contract.

5. Other Information

A. The Arctic Research area of the Geomechanics Program at Flow Research Company expects to have a U.S. government contract with the Office of Naval Research, entitled "Background Noise Generated by Sea Ice Deformations," in the amount of $100,000.

B. The FRC personnel to be assigned for direct work on this project include:

Dr. R. S. Pritchard, PI, Sr. Research Scientist, Manager Geomechanics Department.
Mr. D. R. Thomas, PI, Research Scientist, Geomechanics Department
Dr. J. J. Kollé, Research Scientist, Geomechanics Department
Dr. J. C. Schedvin, Research Scientist, Oceanography Department
Mr. Pat McCafferty, Computer Programmer

In addition, we have retained Dr. Miles G. McPhee, an Arctic oceanographic consultant, to help define and interpret ocean current data over the Chukchi Sea Continental Shelf. Dr. McPhee is an experienced scientist whose involvement with FRC scientists began during AIDJEX. He brings a special knowledge of ocean current modeling, especially the effects of ocean currents or sea ice dynamics modeling, to the research team.

Resumes of R. S. Pritchard, D. R. Thomas, and M. G. McPhee are included on the following pages.

C. Persons authorized to conduct negotiations for Flow Research Company are:

Ms. Mary Chandra, Contract Administrator (206) 872-8500
Mr. Roger Haines, Vice President for Finance & Administration (206) 872-8500
Dr. K. J. Touryan, Sr. Vice President and General Manger of Flow Research Company (206) 872-8500

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Senior Research Scientist
Manager, Geomechanics Department

Home Address:

11042 Sand Point Way N.E., Seattle, Washington 98125.
Telephone (206) 365-5377

Education:

B.S., Engineering Mechanics, Lehigh University, 1962.
M.S., Mechanical Engineering, University of New Mexico, 1966.
Ph.D., Engineering, University of New Mexico, 1970.

Experience:

Associate Design Engineer, ACF Industries, Inc., Albuquerque, New Mexico, 1962- 1963.

Research Engineer, Eric H. Wang Civil Engineering Research Facility, University of New Mexico, Albuquerque, New Mexico, 1968 - 1973.

Principal Scientist, Arctic Ice Dynamics Joint Experiment, University of Washington, Seattle, Washington, 1973 - 1978.

Consultant, R. S. Pritchard Consulting, 1975 - 1978.

Senior Research Scientist, Manager, Geomechanics Department, Flow Research Company, Kent, Washington; 1978.

Specialization:

Solid mechanics, applied mathematics, plasticity, numerical analysis, Technology transfer from mechanics to important applied problems in geomechanics.

Professional Societies:

American Academy of Mechanics
American Geophysical Union American Society of Mechanical Engineers
International Society for Rock Mechanics Phi Kappa Phi Pi Tau Sigma
Society of Sigma Xi

Publications:

Dr. Pritchard has authored or co-authored over fifty-three publications and reports, primarily in the area of ice, soil and rock mechanics.

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Manager, Geomechanics Department .

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MR. DONALD R. THOMAS

Research Scientist

Home Address:

2007E. Miller, Seattle, Washington 98112. Tel. (206) 325-2804

Education:

Army Electronics, Ft. Monmouth, New Jersey, and Sandia Base, New Mexico, 1959.
B.S., Mathematics, University of Oregon, 1966.
Statistics and Japanese, Portland State University, 1973.

Experience:

U.S. Army Electronics, 1958 - 1961.

Technician, Institute of Molecular Biology, University of Oregon, Eugene, Oregon, 1963 - 1966.

Programmer, Child Study Clinic, University of Oregon Dental School, Portland, Oregon, 1966 - 1973.

Scientific Programmer, Arctic Ice Dynamics Joint Experiment, Seattle, Washington, 1973 - 1978.

Research Scientist, Flow Research Company, Kent, Washington, 1978 - Present.

Specialization:

Computer programming, statistics, numerical modeling, ice dynamics.

Publications:

1. C. Sanin, B. S. Savara, Q. D. Clarkson and D. R. Thomas, "Prediction of Occlusion by Measurements of the Deciduous Dentition," American Journal of Orthodontics, Vol. 57, No. 6, June 1970.

2. C. Sanin, B. S. Savara, D. R. Thomas and Q. D. Clarkson, "Arc Length of the Dental Arch Estimated by Multiple Regression," Journal of Dental Research, Vol. 49, No. 4, July - August 1970.

3. S. Nakamura, B. S. Savara and D. R. Thomas, "Norms of Size and Annual Increments of the Sphenoid Bone from 4 to 16 Years," The Angle Orthodontist, Vol. 42, No. 1, January 1972.

MR. DONALD R. THOMAS

Research Scientist

Publications: (Cont.)

4. S. Nakamura, B. S. Savara and D. R. Thomas, "Facial Growth of Children with Cleft Lip and/or Palate," Cleft Palate Journal, Vol. 9, No. 2, April 1972.

5. D. Thomas, "Snow Anchors," OFF BELAY, June 1972, No. 3.

6. J. F. Nye and D. R. Thomas, "The Use of Satellite Photographs to Give the Movement and Deformation of Sea Ice," AIDJEX Bulletin No. 27, University of Washington, Seattle, Washington, November 1974.

7. R. S. Pritchard and D. R. Thomas, "Response of Sea Ice to One-Dimensional Driving Forces and Boundary Perturbations," AIDJEX Bulletin No. 38, University of Washington, Seattle, Washington, March 1978.

8. D. R. Thomas and R. S. Pritchard, "Beaufort and Chukchi Sea Ice Motion - Part 1. Pack Ice Trajectories," Environmental Assessment of the Alaskan Continental Shelf, Annual reports of Principal Investigators, Vol. VIII, Transport, 1979. Also published as Flow Research Report No. 133, Flow Research Company, Kent, Washington, March 1979.

9. R. S. Pritchard, M. D. Coon and D. R. Thomas, "Modeling the Mechanical Energy Budget of the Beaufort Sea Ice Cover," Flow Research Report No. 137R, Flow Research Company, Kent, Washington, 1979.

10. D. R. Thomas and R. S. Pritchard, "Oil Movement in the Ice Covered Beaufort and Chukchi Sea," in The Physical Behavior of Oil in the Marine Environment, Proceedings of a workshop held at Princeton University, May 8 and 9, 1979. Also in Flow Research Report No. 138, Flow Research Company, Kent, Washington, 1979.

11. R. S. Pritchard and D. R. Thomas, "The Range of Influence of Boundary Parameters in the AIDJEX Model," in Sea Ice Processes and Models (cd. R. S. Pritchard), University of Washington Press, Seattle, Washington, 1980.

12. D. R. Thomas and R. S. Pritchard, "Beaufort Sea Ice Mechanical Energy Budget 1975-76," Flow Research Report No. 165, Flow Research Company, Kent, Washington, 1980.

13. D. R. Thomas, "Behavior of Oil Spills Under Sea Ice-Prudhoe Bay," Flow Research Report No. 175, Flow Research Company, Kent, Washington, 1980.

MR. DONALD R. THOMAS

Research Scientist

Publications: (Cont.)

14. D. R. Thomas, "Prudhoe Bay Oil Spill Scenarios," Flow Research Report No. 176, Flow Research Company, Kent, Washington, 1980.

15. D. R. Thomas, "Harrison Bay Sea Ice Conditions Relating to Oil Spills," Flow Research Report No. 189, Flow Research Company, Kent, Washington, 1981.

16. Thomas, D. R. and R. S. Pritchard, Norton Sound and Bering Sea Ice Motion, 1981: Data Report,'' Annual Report to Outer Continental Shelf Environmental Assessment Program on Research Unit 567, National Oceanic and Atmospheric Administration, Boulder, Colorado, to appear.

RESUME (March 1981)

NAME : Miles Gordon McPhee

BORN : 9 August 1946, Yakima, Washington

MARTIAL STATUS: Married, three children

EDUCATION:

B. S., 1068 Stanford University, Civil Engineering (with distinction).
Ph.D., 1974 University of Washington, Geophysical Fluid Dynamics

POST GRADUATE APPOINTMENTS AND EMPLOYMENT:

Engineer, Anderson Bridge Co., Kirland, WA, (1968-1969).

Office Engineer, Guy F. Atkinson Co., Highway Construction Division, South San Francisco, CA., (1969-1970).

Research Assistant, Geophysics program University of Washington, Seattle, WA., (1971-1974).

Research Scientist responsible for oceanic boundary layer studies, AIDJEX, University of Washington, (1974-1978).

Research Geophysicist, Cold Regions Research and Engineering Laboratory (CRREL), (1978-present).

PROFESSIONAL ACTIVITIES:

Organizations

Member, American Geophysical Union
Sponsor, Union of Concerned Scientists

Invited Lectures

University of Miami, 1976
North Carolina State University, 1976
Naval Postgraduate School, 1977
Oregon State University, 1977
Woods Hole Oceanographic Institution, 1978

Workshops and Institutes, Invited Participation

NATO Advanced Study Institute, "Modeling and Prediction of the Upper Layers Of the ocean", Urbino, Italy, September 1975.
FGGE Polar Workshop, Boulder, January, 1976, Rapporteur
NOAA Ice Conference, Seattle, May, 1976
Ocean Forecasting Workshop, Monterey, June, 1976

Workshops and Institutes, Invited Participation (Cent)

ONR "MuMMERS" Workshop, Monterey, July, 1976, Rapporteur, Meteorology/ice dynamics panel.
Marine Sciences Board, Panel on Polar Ocean Engineering, Seattle, February, 1978.
Workshop on Eastern Arctic Research, Copenhagen, January, 1-979.
Workshop on the Seasonal Sea Ice Zone, Monterey, February, 1979, Authored review paper for Oceanography Panel.
NASA Cryosphere Workshop, Greenbelt, MD, September, 1979, Chairman, Sea Ice/Oceanography Panel.
European Basin Experiment (EUBEX) Workshop, Seattle, November, 1979, Elected to EUBEX Planning Committee.

PUBLICATIONS:

1972 McPhee, M.G. and J.D. Smith. Flow in the vicinity of a small pressure ridge keel. (abstract) *EOS, Transactions of the American Geophysical Union, 53,* p. 1011.

1974 McPhee, M.G. Turbulent and mean structures of flow in the boundary layer under pack ice, (abstract). *EOS, Transactions of the American Geophysical Union, 55,* p. 322.

McPhee, M.G., An experimental investigation of the boundary layer under pack ice. Ph.D. Thesis, Geophysics Program; also *Technical Report M75-14,* Department of Oceanography, University of Washington, Seattle, WA 164 pp.

1975 McPhee, M.G. and J.D. Smith, Measurements of the turbulent boundary layer under pack ice. *AIDJEX Bulletin, No. 29.,* University of Washington, Seattle, WA pp. 49-92.

McPhee, M.G., Ice-ocean momentum transfer for the AIDJEX ice model, *AIDJEX Bulletin No. 29,* University of Washington, Seattle, WA pp. 93-111.

McPhee, M.G., The effect of ice motion on the mixed layer under arctic pack ice. *AIDJEX Bulletin, No. 30,* pp. 1-27.

1976 McPhee, M.G., A simple model for inertial oscillations in a combined sea ice-upper ocean system, (abstract). *Bulletin of the American Meteorological Society, 57,* p. 155.

Pritchard, R.S., M. D. Coon, and M.G. McPhee, Simulation of sea ice dynamics during AIDJEX. *AIDJEX Bulletin, No. 34,* pp. 73-93.

McPhee, M.G. and J.D. Smith, Measurements of the turbulent boundary layer under pack ice. *Journal of Physical Oceanography, 6, No. 5,* Sept. *1976,* pp. 969-711 (modified version of 1975 AIDJEX Bulletin article).

PUBLICATIONS (Cent)

1976 McPhee, M.G., Water stress sub-model for the AIDJEX model. *Proceeding of the Third International Conference on Port and Ocean Engineering Under Arctic Conditions, 11-15* August, 1975, Fairbanks, Alaska. pp. 495-508.

1977 McPhee, M.G., Upper ocean current measurements at manned drift stations in the Arctic, (Abstract). *EOS, Transactions of the American Geophysical Union, 58,* p. *164.*

McPhee, M.G. and L. Mangum, Current meter measurements from drifting data buoys in the Arctic, (abstract). *EOS, Transactions of the American Geophysical Union, 58,* p. *164.*

McPhee, M.G., A simulation of inertial oscillations in the drift of manned ice stations, *AIDJEX Bulletin No. 36,* pp. 65-85.

Pritchard, R., M. Coon, M.G. McPhee, and E. Leavitt, Winter ice dynamics in the nearshore Beaufort Sea. *AIDJEX Bulletin No. 37,* pp. 37-94.

Pritchard, R., M. Coon, and M.G. McPhee, Simulation of sea ice dynamics during AIDJEX. *Journal* of *Pressure Vessel Technology, Transactions of the ASME, 99,* Series J., No. *3,* August 1977, pp. 491-407. (Modified version of 1976 AIDJEX Bulletin Article).

McPhee, M.G., An analysis of pack ice drift in summer, paper presented at and accepted for publication, *Symposium on Sea Ice Processes and Models, sponsored by the International Commission on Snow and Ice and AIDJEX, Seattle, Sept. 6-9.*

McPhee, M.G., A simple model for the boundary layer under pack ice (abstract). *EOS, Transaction of the American Geophysical Union, 58,* p. *1152.*

McPhee, M.G., on boundary-layer scaling and the drift of pack ice, *Ocean ModelZing* (Newsletter, SCOR WG *49), No. y,* pp. *3-6.*

1978 McPhee, M.G., A simulation of inertial oscillation in drifting pack ice. *Dynamics of Atmospheres and Ocean-s, 2,* pp. 107-122.

McPhee, M.G., The free-drift velocity field across the AIDJEX manned array. *AIDJEX Bulletin No.* 38, pp. 158-170.

McPhee, M.G., AIDJEX oceanographic report. *AIDJEX Bulletin No. 39,* pp. *33-78.*

McPhee, M.G., L. Mangum, and P. Martin, Performance of met-ocean buoys in AIDJEX. *AIDJEX Bulletin No. 40,* pp. *35-59.*

PUBLICATIONS (Cent)

1978 McPhee, M.G., Horizontal variation of inertial oscillation in drifting sea ice, (abstract). *EOS, Transactions of the American Geophysical Union*, 59, p. 1094.

1979 McPhee, M.G., The effect of the oceanic boundary layer on the mean drift of pack ice: Application of a simple model. *Journal of Physical Oceanography, 9*, pp. 388-400. (Also appeared *in AIDJEX Bulletin, No. 39,* pp. 1-32).

McPhee, M.G., Some thoughts and a few data on *Modelling and Prediction of the Upper Layers of the Ocean, Ocean Modelling,* (Newsletter, SCOR WG 49) No. 20., pp. 1-3.

McPhee, M.G., Physical oceanography of the seasonal sea ice zone, Invited review paper, Seasonal Sea Ice Zone Workshop, 26 February to 1 March 1979, Monterey, CA. Proceedings to be published.

McPhee, M.G., Mechanisms for cross-pycnocline mixing in the Arctic, (abstract), *Bulletin of the American Meteorological Society, 60,* p. *848.*

1980 McPhee, M.G., A study of oceanic boundary-layer characteristics including inertial oscillation at three drifting stations in the Arctic Ocean, *Journal of Physical Oceanography 10,* p. *870-884.*

McPhee, M.G., Oceanic heat flux in the Arctic: A peculiar thermohaline regime, *Ocean Modelling,* (Newsletter, SCOR WG *49),* No. 31 pp. 1-4.

McPhee, M.G., Heat transfer across the salinity-stabilized pycnocline of the Arctic Ocean. Paper presented at the Second International Symposium on Stratified Flows, Trondheim, Norway, 24-27 June 1980, proceedings to be published.

McPhee, M.G., and N. Untersteiner, Oceanic heat flux at FRAM I inferred from ice growth and temperature gradients, (abstract) *EOS, Transactions of the American Geophysical Union, 61,* p. 278.

McPhee, M.G., Physical oceanography of the Seasonal Sea Ice Zone, *Cold Regions Science and Technology, 2,* 93-118.

McPhee, M.G., An analysis of pack ice drift in summer. *Sea Ice Processes* and *Models,* R.S. Pritchard, cd., University of Washington Press, Seattle, 62-75.

1981 McPhee, M.G. and N. Untersteiner, Using sea ice to measure vertical heat flux in the ocean. Submitted to *Journal* of *Geophysical Research.*

McPhee, M.G., Upper ocean temperature, salinity, and density in the vicinity of Arctic drift station, FRAM 1, March to May, 1979, *USACRREL Special Report 81-5.*

PUBLICATIONS (Cent)

1981 McPhee, M.G., Sea ice drag laws **and** simple boundary **layer** concepts, including application to rapid melting. Submitted to *Reviews of Geophysics and Space Physics*.

McPhee, M.G., An analytic similarity theory for the planetary boundary layer stabilized by surface buoyancy. To appear in *Boundary-Layer Meteorology*.

McPhee, M.G., Access to STD Data, *USACRREL Internal Report 704.*

McPhee, M.G., AIDJEX position, drift, wind, and current data, *USACRREL Internal Report 705*.

6. Forms

The forms listed below are included on the following pages:

a. Property Inventory Form (CD-281]

b. Digital Data Tracking Form

c. Data Submission and Products Schedule

d. Milestone Chart

e. Logistics Requirements

f. Proposed OCSEAP Budget

g. Contract Pricing Proposal Form (Federal Option Form 60)

FORM CD-281
(10-72)
PRESCRIBED BY
HANDBOOK FOR SUPPLY
MANAGEMENT OAO 206-0

U.S. DEPARTMENT OF COMMERCE

DATE OF REPORT	CONTRACT NUMBER
September 1981	03-78-B01-61

NAME AND ADDRESS OF CONTRACTOR (Type or print)
Flow Industries, Inc.
21414-68th Avenue South
Kent, Washington 98031

REPORT OF GOVERNMENT PROPERTY IN POSSESSION OF CONTRACTOR

(See DoC Manual for Control of Government Property by Contractors)

This report covers ☐ expendable ☐ non-expendable property

NAME AND TITLE OF AUTHORIZED REPRESENTATIVE
M.K. Chandra
Contract Administrator

SIGNATURE
Malley Chandra

LIST BELOW EACH ITEM OF GOVERNMENT PROPERTY

GOVERNMENT ID NO. AND FSN	DESCRIPTION OF ITEM	MFR.	MFR. SERIAL NOS.	QUANTITY	CONDITION	LOCATION	COST	DATE RECEIVED
	None							

IC 190-P73

DIGITAL DATA TRACKING FORM

RU NUMBER 567

PI NAME Pritchard

FILE TYPE	FILE ID.	PLATFORM	SURVEY START DA/MO/YR	SURVEY END DA/MO/YR	EXPECTED SUBMISSION DATE DA/MO/YR
NODC-056		ADAP drift buoys	Jan 81	Jun 81	Sep 81

DATA SUBMISSION AND PRODUCTS SCHEDULE

Data Type (i.e. Intertidal, Benthic Organisms, etc.)	Media (Cards, coding sheets, tapes, disks)	Estimated Volume (Volume of processed data)	OCSEAP format (If known)	Processing and Formating done by Project (Yes or No)	Collection Period (Month/Year to Month/Year)	Submission (Month/Year)
Ice Motion	Mag Tape	10,000 positions	unknown	yes	Dec 81 to Aug 82	Nov 82
Atmospheric Pressure	Mag Tape	3,000 pressure measurements	unknown	yes	Dec 81 to Aug 82	Nov 82
Ocean Currents	Mag Tape	4,000 current measurements	unknown	yes	Feb 82 to Aug 82	Nov 82

MILESTONE CHART

O Planned Completion Date

X - Actual Completion Date
(to be used for updates)

RU # 567 PI: R. S. Pritchard/D. R. Thomas

Major Milestones: Reporting, data management and other significant contractual requirements; periods of field work; workshops; etc.

MAJOR MILESTONES	1981 O	N	D	1982 J	F	M	A	M	J	J	A	S	O	N	D
Deploy First of 3 Buoys			O												
Deploy Second of 3 Buoys					O										
Process Buoy Data				----	----	----	----	----	----	----	----	----	O		
Annual Report							O								
Attend Navarin Basin Synthesis												O			
Norton Sound Data Report		O													
Final Report														O	

LOGISTICS REQUIREMENTS

Please fill in all spaces or indicate not applicable (N/A). Use additional sheets as necessary. Budget line items concerning logistics should be keyed to the relevant item described on these forms.

INSTITUTION Flow Research Company PRINCIPAL INVESTIGATOR Pritchard/Thomas

A. SHIP SUPPORT n/a

1. Delineate proposed tracks and/or sampling grids, by leg, on a chart of the area. Include a list of proposed station geographic positions.

2. Describe types of observations to be made on tracks and/or at each grid station. Include a description of shipboard sampling operations. Be as specific and comprehensive as possible.

3. What is the optimum time chronology of observations on a leg and seasonal basis and what is the maximum allowable departure from these optimum times? (Key to chart prepared under Item 1 when necessary for clarification.)

4. How many sea days are required for each leg? (Assume vessel cruising speed of 10 knots for NOAA vessels. Do not include running time from port to beginning point and from end point to port and do not include a weather factor.)

5. Do you consider your investigation to be the principal one for the operation thus requiring other activities to piggyback or could you piggyback?

6. Approximately how many vessel hours per day will be required for your observations and must these hours be during daylight? Include an estimate of sampling-time on station and sample processing time between stations.

7. What equipment and ship's personnel do you require?

8. What is the approximate weight and volume of equipment you will bring?

9. Will your data or equipment require special handling? _____ If yes, please describe.

10. Will you require any gases and/or chemicals? ______ If yes, they should be on board the ship prior to departure from Seattle or time allowed for shipment by barge.

11. Do you have a ship preference, either NOAA or non-NOAA? _______.
If "yes", please name the vessel and give the reason for so specifying.

12. If you recommend the use of a non-NOAA vessel, what is the per sea day charter cost and have you verified its availability?

13. How many people must you have on board for each leg? Include a list of participants, specifically identifying any who are foreign nationals.

B. AIRCRAFT SUPPORT - FIXED WING

Part 1 - December Deployment

1. Delineate proposed flight lines on a chart of the area. Indicate desired flight altitude on each line. (Note: If flights are for transportation only, chart submission is not necessary but origin and destination points should be listed.)

   Kotzebue - Chukchi Sea - Kotzebue (See Figure 1)

2. Describe types of observations to be made.

   Buoy deployment (air drop) only.

3. What is the optimum time chronology of observations on a seasonal basis and what is the maximum allowable departure from these optimum times? (Key to chart prepared under Item 1 when necessary for clarification.)

   December 1, 1981, or as soon as possible thereafter.

4. How many days of flight operations are required and how many flight hours per day?

   2 days, 1 flight per day (4 hours flight time)

   Total flight hours?

   8 hours total flight time

5. Do you consider your investigation to be the principal one for the flight, thus precluding other activities or requiring other activities to piggyback or could you piggyback?

   Principal activity.

6. What types of special equipment are required for the aircraft (non carry-on)?

   What are the weights, dimensions, power requirements, and installation problems unique to the specific equipment.

   No special equipment but doors must be removed and temporary closure (plywood) provided.

7. What are the weights, dimensions and power requirements of carry-on equipment?

   TAD(A) airdrop buoys: weight (each) - 100 lbs; dimensions (each) - 25" x 25" x 50".

8. What type of aircraft is best suited for the purpose?

   Twin Otter equipped for air drops (See Item 6).

9. Do you recommend a source for the aircraft? no.

   If "yes", please name the source and the reason for your recommendation.

10. What is the per hour charter cost of the aircraft?

    Unknown.

11. How many people are required on board for each flight (exclusive of flight crew)?

One

12. Where do you recommend that flights be staged from?

Kotzebue (but Barrow is okay).

B. AIRCRAFT SUPPORT - FIXED WING part 2 - February Deployment

1. Delineate proposed flight lines on a chart of the area. Indicate desired flight altitude on each line. (Note: If flights are for transportation only, chart submission is not necessary but origin and destination points should be listed.)

Barrow - Chukchi Sea - Barrow (See Figure 2)

2. Describe types of observations to be made.

Buoy deployment - with current meter.

3. What is the optimum time chronology of observations on a seasonal basis and what is the maximum allowable departure from these optimum times? (Key to chart prepared under Item 1 when necessary for clarification.)

February 7, 1981, or as soon as possible thereafter.

4. How many days of flight operations are required and how many flight hours per day?
2 days, 1 flight per day (4 hours flight time plus 1 hour on ice)
Total flight hours? 8 hours total flight time.

5. Do you consider your investigation to be the principal one for the flight, thus precluding other activities or requiring other activities to piggyback or could you piggyback?

Could be coordinated with RU#541 if weight allows.

6. What types of special equipment are required for the aircraft (non carry-on)?

What are the weights, dimensions, power requirements, and installation problems unique to the specific equipment.
NO special equipment but plane must be able to land on the ice.

7. What are the weights, dimensions and power requirements of carry-on equipment?
Ice drill = weight - 100 lbs, dimensions - 3 foot sections
ADAP buoy = weight - 60 lbs, dimensions 16″ x 16″ x 16″.

8. What type of aircraft is best suited for the purpose?

Cessna 180 or 185 with skis.

9. Do you recommend a source for the aircraft? no .
If "yes", please name the source and the reason for your recommendation.

10. What is the per hour charter cost of the aircraft?

Unknown.

•

11. How many people are required on board for each flight (exclusive of flight crew)?

    One

12. Where do you recommend that flights be staged from?

    Barrow.

C. AIRCRAFT SUPPORT - HELICOPTER

1. Delineate proposed transects and/or station scheme on a chart of the area. . (Note: If flights are for transport of personnel or equipment only from base camps to field camps and visa versa, chart submission is **not` necessary** but origin and destination points should be listed).

Kotzebue - Hope Basin - Kotzebue (See Figure 2).

2. Describe types of observations to be made.

Buoy deployment - with current meter.

3. What is the optimum time chronology of observations on a seasonal **basis** and what **is** the maximum allowable departure from these optimum times?

February 7, 1981, or as soon as possible thereafter.

4. How many days of helicopter operations are required and how many flight hours per day? 1 day, 1 flight, 3 flight hours.

Total flight hours? 3 hours total flight time.

, 5. How many people are required on board for each flight (exclusive of the pilot)?
One

6. What are the weights and dimensions of equipment or supplies to be transported?
Ice drill = weight - 100 lbs, dimensions - 3 foot sections.
ADAP buoy = weight - 60 lbs, dimensions - 16" x 16" x 16".

7. What type of helicopter do you recommend for your operations and why?

8. Do you recommend a particular source for the helicopter? ‘°.
If “yes”, please name the source and the reason for your recommendation.

9. What is the per hour charter cost of the helicopter?

Unknown.

10. Where do you recommend that flights be staged from?

Kotzebue

11. **Will** special navigation and communications be required?

No

D. QUARTERS AND SUBSISTENCE SUPPORT N/A

1. What are your requirements for quarters and subsistence in the field area? These requirements should be broken down as follows:

2. Do you recommend a particular source for this support? ___. If "yes", please name the source and the reason for your recommendation.

3. What is your estimated per person day cost for this support at each location?

How did you derive this figure, i.e., is the figure based on established commercial rates at the location, or on estimated costs to establish and maintain a field camp?)

E. SPECIAL LOGISTICS PROBLEMS

1. What special logistics problems do you anticipate under your proposal and how do you propose that the problems be solved? (Provide cost estimates and indicate whether you propose handling the problems yourself or whether you must depend on NOAA to solve them for you?

RU 561

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget
Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 1

NAME OF OFFEROR
Flow Industries, Inc.

HOME OFFICE ADDRESS
21414 - 68th Avenue South
Kent WA 98031

SUPPLIES AND/OR SERVICES TO BE FURNISHED
FRC Proposal No. 8217 entitled "The Transport & Behavior of Oil Spilled In and Under Sea Ice"
Period of Support: 10/81 - 12/82

DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED
Flow Research Company

TOTAL AMOUNT OF PROPOSAL
$ 60,000

GOV'T SOLICITATION NO

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL (Itemize on Exhibit A)					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				-0-	
2. MATERIAL OVERHEAD[3] (Rate %X$ base =)				-0-	
3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
Dr. R. Pritchard	240	25.84	6,202		
Mr. D. Thomas	300	17.39	5,217		
Research Scientist	80	15.43	1,234		
Computer Programmer	70	8.00	560		
TOTAL DIRECT LABOR				13,213	
4. LABOR OVERHEAD (Specify Department or Cost Center)[3]	O.H. RATE	X BASE =	EST COST ($)		
	85	13,213	11,231		
TOTAL LABOR OVERHEAD				11,231	
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION			2,745		
b. PER DIEM OR SUBSISTENCE			2,430		
TOTAL TRAVEL				5,175	
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
Dr. Miles McPhee 15 days @ $250/day			3,750		
TOTAL CONSULTANTS				3,750	
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				10,619	
10. TOTAL DIRECT COST AND OVERHEAD				43,988	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate 24 % of cost element Nos. 10)[3]				10,557	
12. ROYALTIES[4]				-0-	
13. TOTAL ESTIMATED COST				54,545	
14. FEE OR PROFIT				5,455	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				60,000	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to (Describe RFP, etc.)

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Dr. K. J. Touryan, Senior Vice President and General Manager	K. J. Touryan

NAME OF FIRM	DATE OF SUBMISSION
Flow Research Company, a division of Flow Industries, Inc.	9/23/81

EXHIBIT A-SUPPORTING SCHEDULE (Specify. If more space is needed, use reverse)

COST EL NO.	ITEM DESCRIPTION (See footnote 5)	EST COST ($)
7.	Travel Costs	
	. 1 Rnd Trip Coach Airfare Sea/Juneau/Sea	410
	. 1 Rnd Trip Coach Airfare Sea/Barrow/Sea	925
	. 2 Rnd Trip Coach Airfares Sea/Kotzebue/Sea	1,410
	. Subsistence: 18 days @ $135/day	2,430
	TOTAL TRAVEL COSTS	$5,175
9.	Other Direct Costs	
	. Fringe Benefits	4,219
	. State Business & Occp. Tax	600
	. Expendable. Supplies	500
	. Shipping Costs	600
	. Data Retrieval Cost from World Data Center	500
	. Technical Services 100 hours @ $21/hour	2,100
	. PRIME Computer @ $210/hour	2,100
	TOTAL OTHER DIRECT COSTS	$10,619

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO (If yes, identify below.)

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, 815 Airport Way South, Seattle, WA 98134	(206) 442-4770

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO (If yes, identify on reverse or separate page)

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[X] YES [ ] NO (If yes, identify.): [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEE LOANS

IV. DO YOU NOW HOLD ANY CONTRACT (Or, do you have any independently financed (IR&D) projects) FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO (If yes, identify.):

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO (If no, explain on reverse or separate page)

See Reverse for Instructions and Footnotes

OPTIONAL FORM 60 (10-71)

PROPOSED RESEARCH UNIT BUDGET

A	DIRECT LABOR :	Hours	Rate/Hour	Estimated Cost	
A 1	Employee(s) :				
	Dr R Pritchard	240	25.84	6202	
	D. R. Thomas	300	17.39	5217	
	Research Scientist	80	15.43	1234	
	Computer Programmer	70	8.00	560	
				Total	13,213
A 2	Benefits:	%	X Base =		
			13,2 3	4219	
				Total	4,219
A 3	Overhead:	%	X Base =		
		85	13,213	11,231	
				Total	11,231
				TOTAL FOR A	28,663

B	OTHER DIRECT COSTS: (Itemize Travel & Per Diem)	Estimated Cost	
B 1	Travel: (for field trips)-		
	1-Rnd Trip Coach Airfare Sea/Juneau/Sea	410	
	1-Rnd Trip Coach Airfare Sea/Barrow/Sea	925	
	2-Rnd Trip Coach Airfares Sea/Kotzebue/Sea	1.410	
	Subsistence: 18 days @ $135/day	2.430	
		Total	5,175
B 2	Transport of Equipment & Supplies:	Estimated Cost	
	Expendable Supplies	500	
	Shipping Costs	600	
		Total	1,100
B 3	Rent: (Space & Equipment)	Estimated Cost	
		Total	-0-
B 4	Utilities: (e.g., Data Lines)	Estimated Cost	
		Total	- -
B 5	Printing & Reproduction:	Estimated Cost	
		Total	-0-
B6a	Data Processing (In Required Format):	Estimated Cost	
	Data Retrieval from World Data Center	'inn	
		Total	500
B6b	Data Processing (NOAA Provided) (Do Not Include) (In Total)	Estimated Cost	
B7a	Logistics (Aircraft):	Estimated Cost	
B7b	Logistics (Helicopter):	Estimated Cost	
B7c	Logistics (Ship/Boat):	Estimated Cost	
		Total	- -

B	OTHER DIRECT COSTS: (Continued)	Estimated Cost
B 8	Logistics (NOAA Provided) :(Do Not Include in Total)	

B 9	~~Subcontracts~~: Consultants	Estimated Cost
	Dr. Miles McPhee 15 days @ $250/day	3,750
		Total, 3,750

B10	Inhouse Services: (e. g., Drafting)	Estimated Cost
	Technical Services 100 hours @ $21/hour	2,100
	PRIME Computer @ $210/hour	2,100
		Total 4,200

B11	Expendable Supplies:	Estimated Cost
		Total

B12	Non-Expendable Equipment:	Estimated Cost
		Total

B13	~~ADP Equipment~~: Other Misc. Costs	Estimated Cost
	State Business Tax	600
		Total 600
		TOTAL FOR B 15,325

C	INDIRECT COSTS: (e.g., Fees—Please Specify)	Estimated Cost
	General & Administrative Expense	10,557
	Fee	5,455
		TOTAL FOR C 16,012

PROPOSED RESEARCH UNIT BUDGET TOTAL 60.000

D	REMARKS :